Proceedings of the Indiana Academy of Science

1898

PROCEEDINGS

OF THE

Indiana Academy of Science

1898.

EDITOR, - - - GEO. W. BENTON.

ASSOCIATE EDITORS:

C. A. WALDO, W. A. NOYES,
C. H. EIGENMANN, STANLEY COULTER,
V. F. MARSTERS, THOMAS GRAY,
M. B. THOMAS, JOHN S. WRIGHT.

INDIANAPOLIS, IND.
1899.

INDIANAPOLIS:
WM. B. BURFORD, PRINTER,
1899.

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An Act to provide for the publication of the reports and papers of the Indiana Academy of Science.

[Approved March 11, 1895.]

Preamble.

Whereas, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State, and,

Whereas, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form, and,

Whereas, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement, therefore,

Publication of the reports of the Indiana Academy of Science.

Section 1. *Be it enacted by the General Assembly of the State of Indiana*, That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided, shall be published by and under the direction of the Commissioners of Public Printing and Binding.

Editing reports.

Sec. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Academy of Science, who shall not, by reason of such services, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports, shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery. Not less than 1,500 nor more than 3,000 copies of each of said reports shall be published, the size of the edition within said limits, to be determined by the

Number of printed reports.

concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894. Proviso.

SEC. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through its editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Indiana Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture. Disposition of reports.

SEC. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage. Emergency.

AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

[Approved March 5, 1891.]

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana*, That it shall be unlawful for any person to kill any wild bird other than a game bird, or purchase, offer for sale any such wild bird after it has been killed, or to destroy the nests or the eggs of any wild bird. Birds.

SEC. 2. For the purpose of this act the following shall be considered game birds; the Anatidæ, commonly called swans, geese, brant, and river and sea ducks; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly Game birds.

known as shore birds, plovers, surf birds, snipe, woodcock and sandpipers, tattlers and curlews; the Gallinæ, commonly known as wild turkeys, grouse, prairie chickens, quail, and pheasants, all of which are not intended to be affected by this act.

Penalty.

SEC. 3. Any person violating the provisions of Section 1 of this act shall, upon conviction, be fined in a sum not less than ten nor more than fifty dollars, to which may be added imprisonment for not less than five days nor more than thirty days.

Permits.

SEC. 4. Sections 1 and 2 of this act shall not apply to any person holding a permit giving the right to take birds or their nests and eggs for scientific purposes, as provided in Section 5 of this act.

Permits to Science.

SEC. 5. Permits may be granted by the Executive Board of the Indiana Academy of Science to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to said Board written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege and pay to said Board one dollar to defray the necessary expenses attending the granting of such permit, and must file with said Board a properly executed bond in the sum of two hundred dollars, signed by at least two responsible citizens of the State as sureties. The bond shall be forfeited to the State and the permit become void upon proof that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section and shall further be subject for each offense to the penalties provided in this act.

Bond.

Bond forfeited.

Two years.

SEC. 6. The permits authorized by this act shall be in force for two years only from the date of their issue, and shall not be transferable.

Birds of prey.

SEC. 7. The English or European house sparrow (passer domesticus), crows, hawks, and other birds of prey are not included among the birds protected by this act.

Acts repealed.

SEC. 8. All acts or parts of acts heretofore passed in conflict with the provisions of this act are hereby repealed.

Emergency.

SEC. 9. An emergency is declared to exist for the immediate taking effect of this act, therefore the same shall be in force and effect from and after its passage.

Taking Fish for Scientific Purposes.

Section 2, Chapter XXX, Acts of 1899, page 45, makes the following provision for the taking of fish for scientific purposes: "Provided, That in all cases of scientific observation he [the Commissioner of Fisheries and Game] shall require a permit from the Indiana Academy of Science."

OFFICERS, 1898-99.

President,

CARL H. EIGENMANN.

Vice-President,

D. W. DENNIS.

Secretary,

JOHN S. WRIGHT.

Assistant Secretary,

E. A. SCHULTZE.

Press Secretary,

GEO. W. BENTON.

Treasurer,

J. T. SCOVELL.

EXECUTIVE COMMITTEE.

C. H. Eigenmann,
D. W. Dennis,
John S. Wright,
E. A. Schultze,
G. W. Benton,
J. T. Scovell,
C. A. Waldo,
Thomas Gray,
Stanley Coulter,
Amos W. Butler,
W. A. Noyes,
J. C. Arthur,
J. L. Campbell,
O. P. Hay,
T. C. Mendenhall,
John C. Branner,
J. P. D. John,
John M. Coulter,
David S. Jordan.

CURATORS.

BOTANY ....J. C. Arthur.
ICHTHYOLOGY ....C. H. Eigenmann.
HERPETOLOGY, MAMMALOGY, ORNITHOLOGY ....Amos W. Butler.
ENTOMOLOGY ....W. S. Blatchley.

COMMITTEES, 1898-99.

PROGRAM.

M. B. THOMAS, C. R. DRYER.

MEMBERSHIP.

D. W. DENNIS, R. J. ALEY, E. A. SCHULTZE.

NOMINATIONS.

W. A. NOYES, J. C. ARTHUR, A. L. FOLEY.

AUDITING.

J. L. CAMPBELL, W. E. STONE.

STATE LIBRARY.

A. W. BUTLER, W. A. NOYES, C. A. WALDO, A. W. DUFF, J. S. WRIGHT.

LEGISLATION FOR THE RESTRICTION OF WEEDS.

J. C. ARTHUR, STANLEY COULTER, J. S. WRIGHT.

PROPAGATION AND PROTECTION OF GAME AND FISH.

C. H. EIGENMANN, A. W. BUTLER, W. S. BLATCHLEY.

EDITOR.

GEO. W. BENTON, 525 N. Pennsylvania St., Indianapolis.

DIRECTORS OF BIOLOGICAL SURVEY.

C. H. EIGENMANN, V. F. MARSTERS, J. C. ARTHUR.

RELATIONS OF THE ACADEMY TO THE STATE.

C. A. WALDO, A. W. BUTLER, R. W. MCBRIDE.

GRANTING PERMITS FOR COLLECTING BIRDS.

A. W. BUTLER, C. H. EIGENMANN, W. S. BLATCHLEY.

DISTRIBUTION OF THE PROCEEDINGS.

A. W. BUTLER, J. S. WRIGHT, G. W. BENTON.

OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

	President.	Secretary.	Asst. Secretary.	Press Secretary.	Treasurer.
1885–6	David S. Jordan	Amos W. Butler			O. P. Jenkins.
1886–7	John M. Coulter	Amos W. Butler			O. P. Jenkins.
1887–8	J. P. D. John	Amos W. Butler			O. P. Jenkins.
1888–9	John C. Branner	Amos W. Butler			O. P. Jenkins.
1889–90	T. C. Mendenhall	Amos W. Butler			O. P. Jenkins.
1890–1	O. P. Hay	Amos W. Butler			O. P. Jenkins.
1889–2	J. L. Campbell	Amos W. Butler			C. A. Waldo.
1892–3	J. C. Arthur	Amos W. Butler	Stanley Coulter. W. W. Norman.		C. A. Waldo.
1893–4	W. A. Noyes	C. A. Waldo	W. W. Norman		W. P. Shannon.
1894–5	A. W. Butler	John S. Wright	A. J. Bigney		W. P. Shannon.
1895–6	Stanley Coulter	John S. Wright	A. J. Bigney		W. P. Shannon.
1896–7	Thomas Gray	John S. Wright	A. J. Bigney		W. P. Shannon.
1897–8	C. A. Waldo	John S. Wright	A. J. Bigney	Geo. W. Benton	J. T. Scovell.
1898–9	C. H. Eigenmann	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.

CONSTITUTION.

ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, the State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

SEC. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars, and thereafter an annual fee of one dollar. Any person who shall at one time

contribute fifty dollars to the funds of this Academy, may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

Sec. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

ARTICLE III.

Section 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a president, vice-president, secretary, assistant secretary, press secretary, and treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-presidents of the Academy, shall constitute an executive committee. The president shall, at each annual meeting appoint two members to be a committee which shall prepare the programmes and have charge of the arrangements for all meetings for one year.

Sec. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the executive committee. There shall also be a summer meeting at such time and place as may be decided upon by the executive committee. Other meetings may be called at the discretion

of the executive committee. The past presidents, together with the officers and executive committee, shall constitute the Council of the Academy, and represent it in the transaction of any necessary business not specially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The president shall deliver a public address on the evening of one of the days of the meeting at the expiration of his term of office.

3. The press secretary shall attend to the securing of proper news paper reports of the meetings and assist the secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the president and countersigned by the secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of busi ness.

MEMBERS.

FELLOWS.

R. J. Aley	*1898	Bloomington.
J. C. Arthur	1893	Lafayette.
P. S. Baker	1893	Greencastle.
George W. Benton	1896	Indianapolis.
A. J. Bigney	1897	Moore's Hill.
A. W. Bitting	1897	Lafayette.
W. S. Blatchley	1893	Indianapolis.
J. C. Branner	1893	Stanford University, Cal.
Wm. Lowe Bryan	1895	Bloomington.
Severance Burrage	1898	Lafayette.
A. W. Butler	1893	Indianapolis.
R. E. Call	1894	Brooklyn, N. Y.
J. L. Campbell	1893	Crawfordsville.
John M. Coulter	1893	Chicago, Ill.
Stanley Coulter	1893	Lafayette.
D. W. Dennis	1895	Richmond.
C. R. Dryer	1897	Terre Haute.
A. Wilmer Duff	1896	Lafayette.
C. H. Eigenmann	1893	Bloomington.
A. L. Foley	1897	Bloomington.
Katherine E. Golden	1895	Lafayette.
W. F. M. Goss	1893	Lafayette.
Thomas Gray	1893	Terre Haute.
A. S. Hathaway	1895	Terre Haute.
O. P. Hay	1893	Washington, D. C.
H. A. Huston	1893	Lafayette.
J. P. D. John	1893	Greencastle.
D. S. Jordan	1893	Stanford University, Cal.
Arthur Kendrick	1898	Terre Haute.
Robert E. Lyons	1896	Bloomington.
V. F. Marsters	1893	Bloomington.

* Date of election.

C. L. Mees	*1894	Terre Haute.
T. C. Mendenhall	1893	Worcester, Mass.
Joseph Moore	1896	Richmond.
D. M. Mottier	1893	Bloomington.
W. A. Noyes	1893	Terre Haute.
L. J. Rettger	1896	Terre Haute.
J. T. Scovell	1894	Terre Haute.
Alex. Smith	1893	Chicago, Ill.
Moses C. Stevens	1898	Lafayette.
W. E. Stone	1893	Lafayette.
Joseph Swain	1898	Bloomington.
M. B. Thomas	1893	Crawfordsville.
L. M. Underwood	1893	New York City.
†T. C. Van Nuys	1893	Bloomington.
C. A. Waldo	1893	Lafayette.
F. M. Webster	1894	Wooster, O.
H. W. Wiley	1895	Washington, D. C.
John S. Wright	1894	Indianapolis.

NON-RESIDENT MEMBERS.

D. H. Campbell	Stanford University, Cal.
B. W. Evermann	Washington, D. C.
Charles H. Gilbert	Stanford University, Cal.
C. W. Green	Stanford University, Cal.
C. W. Hargitt	Syracuse, N. Y.
Edward Hughes	Stockton, Cal.
O. P. Jenkins	Stanford University, Cal.
J. S. Kingsley	Tufts College, Mass.
Alfred Springer	Cincinnati, O.
Robert B. Warder	Washington, D. C.
Ernest Walker	Clemson College, S. C.

ACTIVE MEMBERS.

G. A. Abbott	Evansville.
Frederick W. Andrews	Bloomington.

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* Date of election
† Deceased, August 1, 1898.

Curtis Atkinson	Bloomington.
George H. Ashley	Indianapolis.
Edward Ayres	Lafayette.
Timothy H. Ball	Crown Point.
J. A. Bergstrom	Bloomington.
Alexander Black	Greencastle.
Edwin M. Blake	Lafayette.
Lee F. Bennett	Valparaiso.
Donaldson Bodine	Crawfordsville.
M. C. Bradley	Bloomington.
M. A. Brannon	Grand Forks, N. D.
Fred J. Breeze	Pittsburg.
J. A. Brice	
Frank P. Bronson	Indianapolis.
O. W. Brown	
Charles C. Brown	Bloomington, Ill.
H. L. Bruner	Irvington.
A. Hugh Bryan	Lafayette.
J. B. Burris	Cloverdale.
Ada C. Campbell	South Bend.
E. J. Chansler	Bicknell.
Fred M. Chamberlain	Bloomington.
Walter W. Chipman	Warsaw.
George Clements	Crawfordsville.
H. J. Clements	Washington.
Charles Clickener	Tangier.
Mel. T. Cook	Greencastle.
U. O. Cox	Mankato, Minn.
Albert B. Crowe	Ft. Wayne.
M. E. Crowell	Indianapolis.
Glenn Culbertson	Hanover.
Will Cumback	Greensburg.
Alida M. Cunningham	Lafayette.
H. S. Cunningham	Indianapolis.
B. M. Davis	Los Angeles, Cal.
Martha Doan	Westfield.
J. P. Dolan	Syracuse.
Hans Duden	Indianapolis.

Joseph Eastman	Indianapolis.
E. G. Eberhardt	Indianapolis.
M. N. Elrod	Columbus.
F. L. Emory	Morgantown, W. Va.
Percy Norton Evans	Lafayette.
Samuel G. Evans	Evansville.
Carlton G. Ferris	Big Rapids, Mich.
E. M. Fisher	Urmeyville.
J. R. Francis	Indianapolis.
Austin Funk	New Albany.
J. B. Garner	Crawfordsville.
Robert G. Gillum	Terre Haute.
Michael J. Golden	Lafayette.
W. E. Goldsborough	Lafayette.
S. S. Gorby	Franklin.
Vernon Gould	Rochester.
J. C. Gregg	Brazil.
Alden H. Hadley	Melbourne, Fla.
U. S. Hanna	Bloomington.
Chas. A. Helvie	Chicago.
Flora Herr	Bloomington.
Robert Hessler	Indianapolis.
J. A. Hill	
Frank C. Higgins	Terre Haute.
Lucius M. Hubbard	South Bend.
Alex. Johnson	Ft. Wayne.
W. B. Johnson	Franklin.
Chancey Juday	Bloomington.
William J. Karslake	Irvington.
D. S. Kelley	Jeffersonville.
O. L. Kelso	Terre Haute.
A. M. Kenyon	Lafayette.
E. M. Kindle	Bloomington.
Ernest I. Kizer	South Bend.
Charles T. Knipp	Bloomington.
Thomas Large	Evansville.
John Levering	Lafayette.
V. H. Lockwood	Indianapolis.

William A. Macbeth	Terre Haute.
Cora March	Lawrenceburg.
Robert Wesley McBride	Indianapolis.
Rousseau McClellan	Indianapolis.
D. T. McDougal	Minneapolis, Minn.
G. W. Martin	Indianapolis.
Julius B. Meyer	Lafayette.
O. M. Meyncke	Brookville.
Franklin S. Miller	Brookville.
John A. Miller	Bloomington.
W. J. Moenkhaus	San Paulo, Brazil.
H. T. Montgomery	South Bend.
J. P. Naylor	Greencastle.
Charles E. Newlin	Irvington.
John F. Newsom	Stanford University, Cal.
E. W. Olive	Indianapolis.
D. A. Owen	Franklin.
Rollo J. Peirce	Martinsville.
W. H. Peirce	Chicago, Ill.
Ralph B. Polk	Greenwood.
James A. Price	Bloomfield.
Frank A. Preston	Indianapolis.
A. H. Purdue	Fayetteville, Ark.
Ryland Ratliff	Fairmount.
H. G. Reddick	Bloomington.
Claude Riddle	Lafayette.
Bessie C. Ridgley	Chicago, Ill.
D. C. Ridgley	Chicago, Ill.
Curtis A. Rinson	Bloomington.
Giles E. Ripley	Lafayette.
George L. Roberts	Greensburg.
Adolph Rodgers	New Castle.
D. A. Rothrock	Bloomington.
John F. Schnaible	Lafayette.
C. E. Schafer	Huntington.
E. A. Schultze	Ft. Wayne.
Howard Schurmann	Indianapolis.
John W. Shepherd	Terre Haute.

Claude Siebenthal	Bloomington.
G. W. Sloan	Indianapolis.
J. R. Slonaker	Bloomington.
Richard A. Smart	Lafayette.
Harold B. Smith	Worcester, Mass.
Theo. W. Smith	Indianapolis.
Lillian Snyder	Lafayette.
F. P. Stauffer	Logansport.
H. M. Stoops	Brookville.
William Stewart	Lafayette.
George A. Talbert	West Superior, Wis.
Frank B. Taylor	Ft. Wayne.
S. N. Taylor	West Lafayette.
Erastus Test	Lafayette.
F. C. Test	Chicago, Ill.
J. F. Thompson	Richmond.
A. L. Treadwell	Oxford, Ohio.
Daniel J. Troyer	Goshen.
W. P. Turner	Lafayette.
A. B. Ulrey	North Manchester.
W. B. Van Gorder	Knightstown.
Arthur C. Veatch	Rockport.
H. S. Voorhees	Brookville.
J. H. Voris	Huntington.
F. A. Walker	Anderson.
Fred C. Whitcomb	Delphi.
William M. Whitten	South Bend.
Mae Woldt	Irvington.
W. L. Wood	Covington.
William Watson Woollen	Indianapolis.
A. J. Woolman	Duluth, Minn.
J. F. Woolsey	Indianapolis.
A. C. Yoder	Vincennes.
O. B. Zell	Clinton.

Fellows	49
Non-resident members	11
Active members	141
Total	201
Deaths	2

In Memoriam.

JOSEPH W. MARSEE,

Died, Indianapolis, December Third, 1898.

In Memoriam.

THOMAS C. VAN NUYS,

Died, Charlotteville, Virginia, August First, 1898.

LIST OF FOREIGN CORRESPONDENTS.

AFRICA.

Dr. J. Medley Wood, Natal Botanical Gardens, Berea Durban, South Africa.

South African Philosophical Society, Cape Town, South Africa.

ASIA.

China Branch Royal Asiatic Society, Shanghai, China.

Asiatic Society of Bengal, Calcutta, India.

Geological Survey of India, Calcutta, India.

Indian Museum of India, Calcutta, India.

India Survey Department of India, Calcutta, India.

Deutsche Gesellschaft für Natur-und Völkerkunde Ostasiens, Tokio, Japan.

Imperial University, Tokio, Japan.

Koninklijke Naturkundige Vereeniging in Nederlandsch-Indie, Batavia, Java.

Hon. D. D. Baldwin, Honolulu, Hawaiian Islands.

EUROPE.

V. R. Tschusizu Schmidhoffen, Villa Tannenhof, Halle in Salzburg, Austria.

Herman von Vilas, Innsbruck, Austria.

Ethnologische Mittheilungen aus Ungarn, Budapest, Austro-Hungary.

Mathematische und Naturwissenschaftliche Berichte aus Ungarn, Budapest, Austro-Hungary.

K. K. Geologische Reichsanstalt, Vienna (Wien), Austro-Hungary.

K. U. Naturwissenschaftliche Gesellschaft, Budapest, Austro-Hungary.

Naturwissenschaftlich-Medizinischer Verein in Innsbruck (Tyrol), Austro-Hungary.

Editors "Termeszetrajzi Fuzetk," Hungarian National Museum, Budapest, Austro-Hungary.

Dr. Eugen Dadai, Adj. am Nat. Mus., Budapest, Austro-Hungary.

Dr. Julius von Madarasz, Budapest, Austro-Hungary.

K. K. Naturhistorisches Hofmuseum, Vienna (Wien), Austro-Hungary.

Ornithological Society of Vienna (Wien,) Austro-Hungary.

Zoologische-Botanische Gesellschaft in Wien, Wien, Austro-Hungary.

Dr. J. von Csato, Nagy Enyed, Austro-Hungary.

Malacological Society of Belgium, Brussels, Belgium.

Royal Academy of Science, Letters and Fine Arts, Brussels, Belgium.

Royal Linnean Society, Brussels, Belgium.

Societé Belge de Geologie, de Palaeontologie et Hydrologie, Brussels, Belgium.

Societé Royale de Botanique, Brussels, Belgium.

Societé Geologique de Belgique, Liège, Belgium.

Prof. Christian Frederick Lutken, Copenhagen, Denmark.

Bristol Naturalists' Society, Bristol, England.

Geological Society of London, London, England.

Linnean Society of London, London, England.

Liverpool Geological Society, Liverpool, England.

Manchester Literary and Philosophical Society, Manchester, England.

"Nature," London, England.

Royal Botanical Society, London, England.

Royal Geological Society of Cornwall, Penzance, England.

Royal Microscopical Society, London, England.

Zoölogical Society, London, England.

Lieut-Col. John Biddulph, 43 Charing Cross, London, England.

Dr. G. A. Boulenger, British Mus. (Nat. Hist.), London, England.

F. DuCane Godman, 10 Chandos St., Cavendish Sq., London, England.

Hon. E. L. Layard, Budleigh Salterton, Devonshire, England.

Mr. Osbert Salvin, Hawksford, Fernshurst, Haslemere, England.

Mr. Howard Saunders, 7 Radnor Place, Hyde Park, London W., England.

Phillip L. Sclater, 3 Hanover Sq., London W., England.

Dr. Richard Bowlder Sharpe, British Mus. (Nat. His.), London, England.
Prof. Alfred Russell Wallace, Corfe View, Parkstone, Dorset, England.

Botanical Society of France, Paris, France.
Ministèrie de l'Agriculture, Paris, France.
Societé Entomologique de France, Paris, France.
L'Institut Grand Ducal de Luxembourg, Luxembourg, Lux., France.
Soc. de Horticulture et de Botan. de Marseille, Marseilles, France.
Societé Linneenne de Bordeaux, Bordeaux, France.
La Soc. Linneenne de Normandie, Caen, France.
Soc. des Naturelles, etc., Nantes, France.
Zoölogical Society of France, Paris, France.
Baron Louis d' Hamonville, Meurthe et Moselle, France.
Prof. Alphonse Milne-Edwards, Rue Cuvier, 57, Paris, France.

Botanischer Verein der Provinz Brandenburg, Berlin, Germany.
Deutsche Geologische Gesellschaft, Berlin, Germany.
Entomologischer Verein in Berlin, Berlin, Germany.
Journal für Ornithologie, Berlin, Germany.
Prof. Dr. Jean Cabanis, Alte Jacob Strasse, 103 A., Berlin, Germany.
Augsburger Naturhistorischer Verein, Augsburg, Germany.
Count Hans von Berlspsen, Münden, Germany.
Braunschweiger Verein für Naturwissenschaft, Braunschweig, Germany.
Bremer Naturwissenschaftlicher Verein, Bremen, Germany.
Kaiserliche Leopoldische-Carolinische Deutsche Akademie der Naturforscher, Halle, Saxony, Germany.
Königlich-Sächsische Gesellschaft der Wissenschaften, Mathematisch-Physische Classe, Leipzig, Saxony, Germany.
Naturhistorische Gesellschaft zu Hannover, Hanover, Prussia. Germany.
Naturwissenschaftlicher Verein in Hamburg, Hamburg, Germany.
Verein für Erdkunde, Leipzig, Germany.
Verein für Naturkunde, Wiesbaden, Prussia.

Belfast Natural History and Philosophical Society, Belfast, Ireland.
Royal Dublin Society, Dublin.

Societa Entomologica Italiana, Florence, Italy.
Prof. H. H. Giglioli, Museum Vertebrate Zoölogy, Florence, Italy.
Dr. Alberto Perugia, Museo Civico di Storia Naturale, Genoa, Italy.
Societa Italiana de Scienze Naturali, Milan, Italy.
Societa Africana d' Italia, Naples, Italy.
Dell 'Academia Pontifico de Nuovi Lincei, Rome, Italy.
Minister of Agriculture, Industry and Commerce, Rome, Italy.
Rassegna della Scienze Geologiche in Italia, Rome, Italy.
R. Comitato Geologico d' Italia, Rome, Italy.
Prof. Count Tomasso Salvadori, Zoölog. Museum, Turin, Italy.

Royal Norwegian Society of Sciences, Throndhjem, Norway.
Dr. Robert Collett, Kongl. Frederiks Univ., Christiana, Norway.

Academia Real des Sciencias de Lisboa (Lisbon), Portugal.

Comité Geologique de Russie, St. Petersburg, Russia.
Imperial Academy of Sciences, St. Petersburg, Russia.
Imperial Society of Naturalists, Moscow, Russia.

The Botanical Society of Edinburg, Edinburg, Scotland.
John J. Dalgleish, Brankston Grange, Bogside Sta., Sterling, Scotland.
Edinburgh Geological Society, Edinburgh, Scotland.
Geological Society of Glasgow, Scotland.
John A. Harvie-Brown, Duniplace House, Larbert, Stirlingshire, Scotland.
Natural History Society, Glasgow, Scotland.
Philosophical Society of Glasgow, Glasgow, Scotland.
Royal Society of Edinburgh, Edinburgh, Scotland.
Royal Physical Society, Edinburgh, Scotland.

Barcelona Academia de Ciencias y Artes, Barcelona, Spain.
Royal Academy of Sciences, Madrid, Spain.

Institut Royal Geologique de Suède, Stockholm, Sweden.
Societé Entomologique à Stockholm, Stockholm, Sweden.
Royal Swedish Academy of Science, Stockholm, Sweden.

Naturforschende Gesellschaft, Basel, Switzerland.

Naturforschende Gesellschaft in Berne, Berne, Switzerland.

La Societé Botanique Suisse, Geneva, Switzerland.

Societé Helvetique de Sciences Naturelles, Geneva, Switzerland.

Societé de Physique et d' Historie Naturelle de Geneva, Geneva, Switzerland.

Concilium Bibliographicum, Zürich-Oberstrasse, Switzerland.

Naturforschende Gesellschaft, Zürich, Switzerland.

Schweizerische Botanische Gesellschaft, Zürich, Switzerland.

Prof. Herbert H. Field, Zürich, Switzerland.

AUSTRALIA.

Linnean Society of New South Wales, Sidney, New South Wales.

Royal Society of New South Wales, Sidney, New South Wales.

Prof. Liveridge, F. R. S., Sidney, New South Wales.

Hon. Minister of Mines, Sidney, New South Wales.

Mr. E. P. Ramsey, Sidney, New South Wales.

Royal Society of Queensland, Brisbane, Queensland.

Royal Society of South Australia, Adelaide, South Australia.

Victoria Pub. Library, Museum and Nat. Gallery, Melbourne, Victoria.

Prof. W. L. Buller, Wellington, New Zealand.

NORTH AMERICA.

Natural Hist. Society of British Columbia, Victoria, British Columbia.

Canadian Record of Science, Montreal, Canada.

McGill University, Montreal, Canada.

Natural Society, Montreal, Canada.

Natural History Society, St. Johns, New Brunswick.

Nova Scotia Institute of Science, Halifax, N. S.

Manitoba Historical and Scientific Society, Winnepeg, Manitoba.

Dr. T. McIlwraith, Cairnbrae, Hamilton, Ontario.

The Royal Society of Canada, Ottawa, Ontario.

Natural History Society, Toronto, Ontario.

Hamilton Association Library, Hamilton, Ontario.

Canadian Entomologist, Ottawa, Ontario.

Department of Marine and Fisheries, Ottawa, Ontario.

Ontario Agricultural College, Guelph, Ontario.
Canadian Institute, Toronto.
Ottawa Field Naturalists' Club, Ottawa, Ontario.
University of Toronto, Toronto.
Geological Survey of Canada, Ottawa, Ontario.
La Naturaliste Canadian, Chicontini, Quebec.

La Naturale Za, City of Mexico.
Mexican Society of Natural History, City of Mexico.
Museo Nacional, City of Mexico.
Sociedad Cientifica Antonio Alzate, City of Mexico.
Sociedad Mexicana de Geographia y Estadistica de la Republica Mexicana, City of Mexico.

WEST INDIES.

Victoria Institute, Trinidad, British West Indies.
Museo Nacional, San Jose, Costa Rica, Central America.
Dr. Anastasia Alfaro, Secy. National Museum, San Jose, Costa Rica.
Rafael Arango, Havana, Cuba.
Jamaica Institute, Kingston, Jamaica, West Indies.

SOUTH AMERICA.

Argentina Historia Natural Florentine Amegline, Buenos Ayres, Argentine Republic.
Musée de la Plata, Argentine Republic.
Nacional Academia des Ciencias, Cordoba, Argentine Republic.
Sociedad Cientifica Argentina, Buenos Ayres.

Museo Nacional, Rio de Janeiro, Brazil.
Sociedad de Geographia, Rio de Janeiro, Brazil.
Dr. Herman von Jhering, Dir. Zoöl. Sec. Con. Geog. e Geol. de Sao Paulo, Rio Grande do Sul, Brazil.

Deutscher Wissenschaftlicher Verein in Santiago, Santiago, Chili,
Societé Scientifique du Chili, Santiago, Chili.
Sociedad Guatemalteca de Ciencias, Guatemala, Guatemala,

. . . PROGRAM . . .

OF THE

FOURTEENTH ANNUAL MEETING

OF THE

Indiana Academy of Science,

STATE HOUSE, INDIANAPOLIS,

December 28, 29 and 30, 1898.

OFFICERS AND EX-OFFICIO EXECUTIVE COMMITTEE.

C. A. Waldo, President, C. H. Eigenmann, Vice-President, John S. Wright, Secretary.
A. J. Bigney, Asst. Secretary, G. W. Benton, Press Secretary.
J. T. Scovell, Treasurer.

Thomas Gray,	W. A. Noyes,	O. P. Hay,	J. P. D. John,
Stanley Coulter,	J. C. Arthur,	T. C. Mendenhall,	John M. Coulter,
Amos W. Butler,	J. L. Campbell,	John C. Branner,	David Starr Jordan.

The sessions of the Academy will be held in the State House, in the rooms of the State Board of Agriculture.

Headquarters will be at the Bates House. A rate of $2.00 and up per day will be made to all persons who make it known at the time of registering that they are members of the Academy.

Reduced railroad rates for the members can not be obtained under the present rulings of the Traffic Association. Many of the colleges can secure special rates on the various roads. Those who can not do this, could join the State Teachers' Association and thus secure the one and one-third round trip fare accorded to them.

D. W. Dennis,
A. J. Bigney,
Committee.

GENERAL PROGRAM.

Wednesday, December 28.

Meeting of Executive Committee at the Hotel Headquarters .... 8 p. m.

Thursday, December 29.

General Session .... 9 a. m. to 12 m.
Sectional Meetings .... 2 p. m. to 5 p. m.
Address by President C. A. Waldo .... 7 p. m.

Friday, December 30.

General Session, followed by Sectional Meetings .... 9 a. m. to 12 m.
General Session .... 2 p. m. to 4 p. m.

LIST OF PAPERS TO BE READ.

ADDRESS BY THE RETIRING PRESIDENT,

PROFESSOR C. A. WALDO,

At 7 o'clock Thursday evening.

Subject: "The Services of Mathematics."

The address has been placed at this early hour in order that other engagements for the usual hours of evening entertainment may not keep the members of the Academy and their friends from being present.

The following papers will be read in the order in which they appear on the program except that certain papers will be presented "*pari passu*" in sectional meetings. When a paper is called and the reader is not present, it will be dropped to the end of the list, unless by mutual agreement an exchange can be made with another whose time is approximately the same. Where no time was sent with the papers, they have been uniformly assigned ten minutes. Opportunity will be given after the reading of each paper for a brief discussion.

N. B.—By the order of the Academy, no paper can be read until an abstract of its contents or the written paper has been placed in the hands of the Secretary.

GENERAL SUBJECTS.

1. Woollen's Garden of Birds and Botany, 10 m........W. W. Woollen.
2. Plans for the New Buildings of the Biological Station, 10 m.
C. H. Eigenmann and A. C. Yoder.
3. Explorations in the Caves of Missouri and Kentucky, 15 m.
C. H. Eigenmann.
4. Notes on Indigestible Structures in Articles of a Vegetable Diet, 5 m..John S. Wright.
5. The Action of Mercury and Amalgams on Aluminum, 10 m.
G. W. Benton.
6. Field Experiments with Formalin, 8 m............M. B. Thomas.
7. Resistance of Cereal Smuts to Formalin and Hot Water, 15 m.
Wm. Stuart.

*8. The Cell Lineage of Podarke, with considerations on Cleavage in general, 10 m..............................A. L. Treadwell.

9. Lake Maxinkuckee, 10 m..............................J. T. Scovell.

10. An Elevated Beach and Recent Costal Plain, near Portland, Maine, 10 m. . . . . Wm. A. McBeth.
11. Wasted Energy, 10 m. . . . . J. L. Campbell.
12. A Vesuvian Cycle, 10 m. . . . . C. A. Waldo.
13. X Ray Transparency, 10 m. . . . . Arthur L. Foley.
14. The Trouble with Indiana Roads, illustrated with lantern slides, 20 m. . . . . D. B. Luten.

MATHEMATICAL AND PHYSICAL SUBJECTS.

15. Some Tests on Ball Bearings, 15 m. . . . . M. J. Golden.
16. Further Studies in the Propagation of Sound, 20 m. . A. Wilmer Duff.
17. The Intensity of Telephonic Sounds, 5 m. . . . . A. Wilmer Duff.
18. The Distance to which Small Disturbances Agitate a Liquid, 15 m. . . . . A. Wilmer Duff.
*19. A Case of Diamond Fluorescence, 5 m. . . . . A. L. Foley.
20. The Evaporation of Water Covered with a Film of Oil, 10 m. A. Wilmer Duff.
21. A Note on Temperature Co-efficient of Electrical Conductivity of Electrolytes, 10 m. . . . . Arthur Kendrick.
*22. X Rays in Surgery, 10 m. . . . . A. L. Foley.
23. A Common Text-book Error in the Theory of Envelopes, 10 m. Arthur S. Hathaway.
24. A New Triangle and some of its Properties, 10 m. . . . . R. J. Aley.
25. Note on Angel's Method of Inscribing Regular Polygons, 8 m., R. J. Aley.
26. Concurrent Sets of Three Lines Connected with the Triangle. 20 m. . . . . R. J. Aley.
27. Note on "Note on Smith's Definition of Multiplication," 1 m., A. L. Baker.
28. The Geometry of Simson's Line, 25 m. . . . . C. E. Smith.
29. A Bibliography of Foundations of Geometry, 5 m. . . . M. C. Bradley.
30. Point Invariants for the Lie Groups of the Plane, 10 m. D. A. Rothrock.
31. Differential Invariants Derived from Point Invariants, 10 m., D. A. Rothrock.
32. Mathematical Definitions, 10 m. . . . . Moses C. Stevens.

33. **Performance of the Twenty-Million-Gallon Snow Pumping Engine of the Indianapolis Water Company, 5 m......W. F. M. Goss.**
34. **Tests to Determine the Efficiency of Locomotive Boiler Coverings, 5 m...W. F. M. Goss.**
35. **The Leonids of 1898, 5 m.............................John A. Miller.**
36. **A Linear Relation between Certain of Klein's X Functions and Sigma Functions of Lower Stufe, 10 m............John A. Miller.**
37. **A Formula for the Deflection of Car Bolsters, 10 m....W. K. Hatt.**

CHEMICAL SUBJECTS.

38. **Camphoric Acid: Reduction of the Neighboring Xylic Acid, 15 m...W. A. Noyes.**
39. **Alpha hydroxy-dihydro-ciscampholitic Acid, 10 m.**
    W. A. Noyes and J. W. Shepherd.
40. **Iodine Absorption of Linseed Oil, 5 m...P. N. Evans and J. O. Meyer.**

BOTANICAL SUBJECTS.

41. **Some Desmids of Crawfordsville, 10 m..............M. B. Thomas.**
42. **Karyokinesis in the Embryo-sac, with special reference to the behavior of the Chromatin, 10 m...................D. M. Mottier.**
43. **Nuclear Division in Vegetative Cells, 10 m...........D. M. Mottier.**
44. **The Centrosome in Dictyola, 5 m...................D. M. Mottier.**
45. **The Centrosome in Cells of the Gametophyte of Marchantia, 5 m...D. M. Mottier.**
46. **Endosperm Haustoria in Lilium Candidum, 5 m......D. M. Mottier.**
47. **The Effect of Centrifugal Force upon the Cell, 10 m..D. M. Mottier.**
48. **Absorption of Water by Decorticated Stems, 15 m...Giles E. Ripley.**
49. **Indiana Plant Rusts, Listed in Accordance with Latest Nomenclature, 10 m...................................J. C. Arthur.**
50. **The Uredineae of Madison and Noble Counties, with additional Specimens from Tippecanoe County, 10 m..........Lillian Snyder.**
51. **Aspergyllus oryzæ (Ahlburg) Cohn, 20 m......Katherine E. Golden.**
52. **A Red Mould, 10 m.........................Ralph Gibson Curtis.**
53. **The Affinities of the Mycetozoa, 8 m...............Edgar W. Olive.**

54. The Morphological Character of the Scales of Cuscuta, 10 m.
Alida M. Cunningham.

55. Geographical Distribution of the Species of Cuscuta in North America, 10 m. . . . . Alida M. Cunningham.

56. Notes on the Germination of Seedlings of Certain Native Plants, 10 m. . . . . Stanley Coulter.

*57. Re-forestration Possibilities in Indiana, 10 m. . . . . . . Stanley Coulter.

ZOOLOGICAL SUBJECTS.

58. Formalin as a Reagent in Blood Studies, 5 m. . . . . . . Ernest I. Kizer.

59. Species of Diptera, reared in Indiana during the years 1884-1890, 10 m. . . . . F. M. Webster.

60. Distribution of Broods XXII, V and VII, of Cicada Septendecim, in Indiana, 10 m. . . . . F. M. Webster.

61. Some Insects belonging to the Genus Isosoma, reared or captured in Indiana, 10 m. . . . . F. M. Webster.

62. Lake County Crow Roosts, 10 m. . . . . T. H. Ball.

63. The Distribution of Blood Sinuses in the Reptilian Head, 15 m.,
H. L. Bruner.

64. On the Regulation of the Supply of Blood to the Venous Sinuses of the Head of Reptiles, with Description of a New Sphincter Muscle on the Jugular Vein, 15 m. . . . . H. L. Bruner.

65. Note on the Aberrant Follicles in the Ovary of Cymatogaster, 10 m. . . . . George L. Mitchell.

66. Material for the Stúdy of the Variation of Pimephales notatus (Rafinesque), in Turkey Lake and in Shoe and Tippecanoe Lakes, 10 m. . . . . J. H. Voris.

67. Preliminary Note upon the Arrangement of Rods and Cones in the Retina of Fishes, 5 m. . . . C. H. Eigenmann and G. H. Hausell.

68. Degeneration in the Eyes of the Amblyopsidæ, its Plan, Process and Causes, 30 m. . . . . C. H. Eigenmann.

69. The Ear and Hearing of the Amblyopsidæ, 10 m.
C. H. Eigenmann and A. C. Yoder.

70. A Case of Convergence, 15 m. . . . . C. H. Eigenmann.

71. Chologaster agassizii and its Eyes, 5 m. . . . . C. H. Eigenmann.

72. The Eye of Typhlomolge, from the Artesian Wells of San Marcos, Texas, 10 m.........................C. H. Eigenmann.

73. The Eyes of Typhlotriton Spelaeus, 10 m.
C. H. Eigenmann and W. A. Denny.

74. The Blind Rat of Mammoth Cave, 10 m.
C. H. Eigenmann and James R. Slonaker.

*75. Remarks on Birds New to the State Fauna, 10 m......A. W. Butler.

76. A Nematoid Worm in an Egg, 5 m.................Dan J. Troyer.

GEOLOGICAL SUBJECTS.

77. The Geologic Relation of some St. Louis Group Caves and Sink-holes, 10 m....................................Moses N. Elrod.

78. Jug Rock, 5 m...................................Chas. R. Dryer.

†79. The St. Joseph and the Kankakee at South Bend, 10 m.
Chas. R. Dryer.

80. The Meanders of the Muskatatuck at Vernon, Indiana, 5 m.,
Chas. R. Dryer.

81. Old Vernon: A Geographical Blunder, 5 m..........Chas. R. Dryer.

82. Terraces of the Lower Wabash, 10 m..................J. T. Scovell.

83. The Kankakee Valley, 10 m....................H. T. Montgomery.

84. Notes on the Eastern Escarpment of the Knobstone Formation in Indiana, 10 m...............................L. F. Bennett.

*85. A Preglacial Channel on the Falls of Ohio, 3 m....C. E. Siebenthal.

*86. Notes on the Pleistocene Geology of Monroe, Owen and Greene Counties, 10 m................................C. E. Siebenthal.

87. An Old Shore Line, 5 m..........................D. W. Dennis.

88. Two Cases of Variation of Species with Horizon, 5 m..D. W. Dennis.

89. Notes on the distribution of the Knobstone Group in Indiana, 10 m............................J. F. Newsom and J. A. Price.

‡Some Indiana Mildews..........................M. A. Brannon.

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* Author absent. Paper not presented.

† Presented as a part of No. 83.

‡ Paper read at the December meeting, 1889. Not hitherto published; included in this report as a valuable contribution to the State Biological Survey.

FOURTEENTH ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The fourteenth annual meeting of the Indiana Academy of Science was held in Indianapolis, Thursday and Friday, December 29 and 30, 1898, preceded by a session of the Executive Committee of the Academy, 9 p. m., Wednesday, December 28.

At 9 a. m., December 29, President C. A. Waldo called the Academy to order in general session, at which committees were appointed and other routine and miscellaneous business transacted. After the disposition of these affairs, the reading and discussion of papers of the printed program, under the title "General Subjects," occupied the time until adjournment, at 12 m.

The Academy met at 2 p. m. in two sections--biological and physico-chemical—for the reading and discussion of papers. President Waldo presided over the physico-chemical, while J. C. Arthur acted as chairman for the biological section. At 5 p. m. the section meetings adjourned, to meet in general session of the Academy at 7 p. m.

The Executive Committee met at 5:30 p. m., holding a brief session.

Academy met at 7 p. m. Following the disposition of committee reports and other business, the retiring president, Dr. C. A. Waldo, addressed the Academy, first briefly reviewing the progress of scientific work in the State, following with the formal address; subject, "The Services of Mathematics."

Friday, December 30, 9 a. m., the Academy met in general session, with President Waldo in the chair. Following the transaction of business, unread papers were heard and discussed until adjournment, which occurred at 12:15 p. m.

THE FIELD MEETING OF 1898.

The Field Meeting of 1898 was held at Bloomington, Thursday. Friday and Saturday, April 28, 29 and 30.

At 8 p. m. the executive committee met for the transaction of business, after which all visiting members were tendered an informal reception by the local members.

Friday, the 29th, was spent in the field. Leaving Bloomington early in the morning, the party went by rail to Mitchell; from this point it was conveyed by carriage several miles east into a district characterized by caves, subterranean streams and other natural features of much interest.

In the evening, following the return to Bloomington, the Academy was given a reception by the faculty of the Indiana University.

On Saturday, the 30th, members of the Academy made short field excursions in the neighborhood of Bloomington. The success of the meeting was largely due to the efforts of the resident members, who provided means of transportation in the field and spared no pains to make the visit to Bloomington enjoyable.

PRESIDENT'S ADDRESS.

By C. A. Waldo.

INTRODUCTION.

Of the seven volumes of Proceedings published by the Academy or under its direction, it has been my fortune to be more or less intimately connected with the editorial work upon six of them. The general work of the Academy has, therefore, come under my notice in a peculiar way. This fact has led me to attempt a slight departure from the excellent models set by my able predecessors, and to premise the usual discussion expected at this time by a brief resumé of the scientific work recently done in the State, especially during the year 1898.

We may congratulate Indiana upon the amount, the character and the importance of the scientific activity within her borders. In attempting to select a few things for mention we must beforehand pray indulgence. Pardon is asked for sins of omission and commission—these will be because of ignorance or imperfect vision, and for no other reason.

In the following mention, the order of our program for this year is followed.

The mathematicians of the State are showing a commendable zeal in the prosecution of pure and applied mathematics in the higher ranges of the subject, and are building up several centers in which the work done is incomparably beyond that of a generation ago.

Our physicists have been busy investigating electrical, optical and acoustic phenomena and extending our knowledge of these subjects. The year has seen completed within the State a great car-testing plant, the invention of an integrating dynamometer, the completion of investigations on train resistance on straight and curved tracks, and large contributions to engineering literature. Two of our engineering instructors have been honored with important assignments on committees of international importance.

Our chemists have been establishing the value of our coal deposits, have enlarged our knowledge of toxicology, have made special examination of alkaloids and have contributed towards the investigation of food supplies, the exhaustion and restoration of soils.

The year has witnessed, with the co-operation of the Academy, the completion of a treatise on the Phanerogamic Flora of the State, giving the range of nearly 1,500 species, together with specific studies of forests, weeds, and unutilized vegetable resources; this now is awaiting publication.

The year has also seen the culmination of extensive investigations upon beet sugar as a possible Indiana product and the determination of large areas—practically the whole of the northern part of the State—where under existing conditions the sugar beet can be cultivated with profit. Plant disease, like the San José scale on fruit trees or smut on cereals, have received much attention, and valuable results have been obtained. Valuable conclusions have been reached in the use of specific fertilizers for specific plants, and upon the relative merits of surface and sub-irrigation.

Yeast investigations have been continued and further conclusions reached of prime importance to every household.

Additions have been made to our knowledge of cell life and cell modification in plants, as affecting various theories of heredity, and much systematic work has been prosecuted in various parts of the State tending to perfect our knowledge of the State flora. Our denuded lands and their possible reforestration have received scientific attention.

In zoölogy the greatest event of the year has been the issuance from the State Geologist's office of a monograph upon the birds of Indiana. This work is thoroughly up to date and is not a mere catalogue. It gives attention to the economic side of bird life, and enables the farmer to recognize his friends and enemies. No recent extensive scientific publication in the State has created such a widespread interest. An edition of 8,000 has been already exhausted and the demand is for more.

An event of almost equal importance is the removal of the Summer Biological Laboratory from Turkey to Eagle Lake. At the former location many Indiana teachers and scientific workers have been trained in laboratory methods; many more will find their way to the new location and through its influence will enter the ranks of trained specialists. In addition to this, much light is being thrown upon the problem of variation as bearing on the origin of species. During the year there must be credited to Indiana some first-class work on cave fauna which is receiving national attention, and which must have a large bearing upon the problem of the influence of environment.

Animal diseases have been investigated with varying degrees of success, and studies made of food for various forms of live stock.

In the geological work of the year in Indiana, the influence of the new scientific spirit abroad in our midst is especially manifest. Besides the report on birds already referred to, we find in the volume for 1897, recently distributed, a timely revision of Indiana paleontology, and further prosecution of county geological surveys. On the economic side, the clay industries have been well and exhaustively set forth, while the conflicting interests of oil and gas production have received able attention. It will be found eventually that the fearless conservation of our gas deposits will have paid a thousandfold the expense to the State of our geological department. It is refreshing, too, and characteristic of the true scientific spirit, to note how the truth and the whole truth is told of our disappearing gas supply. No permanent prosperity founded on deceit and misrepresentation can come to our commonwealth. Rigorous, unadulterated scientific truth is, however, a sure basis for wealth, honor, morality and happiness.

Naturally flowing out of gas belt indications comes the work of this year—a prospectus of which is given in the volume of 1897.

A thorough investigation and report upon the vast coal deposits of the State is at this time especially opportune. As this investigation has already shown deposits equal to all demands upon it for two hundred years to come, the result of the work can only be to establish us in a confident reliance upon the industrial future of Indiana.

This review would not be at all complete without some notices of a general character. In sociological matters the State is making splendid progress. Along this line there is only time to mention the new pathological laboratory at the Hospital for the Insane, the establishment of the Indiana Reformatory at Jeffersonville, leading to the rational treatment of criminals, the introduction of the Bertillon measurements in four of our cities, and the increased activity in our Board of State Charities. Sanitation in our centers of population, in our public schools and homes and public buildings, is receiving great attention. The agitation for pure food will probably soon lead to advanced legislation on this important subject.

Educationally, nothing perhaps has occurred comparable to the widespread influence resulting from the general dissemination throughout the

State of twenty-five nature study leaflets conspicuously adapted to the wants of our great rural population.

In our educational centers we note with pleasure the extension of laboratories, the growth of cabinets and library facilities. Attention is also called to the gratifying fact that recently the office of State Entomologist has been created and worthily filled.

An event of unusual significance to those who have occasion from time to time to consult the scientific publications in the State Library is the fact that during the year '98 the large and growing science accumulations of the Academy of Science and of the Brookville Natural Science Club have been made available to the general public by being placed upon the shelves of the State Library.

Two thoughts are suggested here as a conclusion:

1. Such valuable results as we are now securing in works like the birds and the phanerogams of the State, its clays and coals, have been reached only by the organization of our scientists, and through their increase and their development of ideas and enthusiasm, resulting certainly in a marked degree from the thirteen years' influence of the Academy of Science.

2. The official relation which we sustain to the State has brought the feet of our scientists to the ground and the economic aspects of their studies are being emphasized as never before.

At best this is but an imperfect and rapidly dissolving view of the teeming and multiplying scientific progress within Indiana's borders. A wise choice of topics would perhaps have given the whole time of this address to a review of progress in Indiana since 1885, but I must leave that inspiring theme to some future historian.

To-night, fellow-workers, I greet you and congratulate you upon work worthily done. Fame may not always follow endeavor, but, whether public recognition of work attempted and results accomplished ever comes or not, the true scientist knows that his highest compensation is in the opportunity for service, and he is at peace with his environment.

Services of Mathematics.

Of the twelve gentlemen who have preceded me in addressing the Indiana Academy of Science on occasions similar to the present, three might have interested you with a mathematical topic, but they did not.

One, famous for his vigorous championship of Christian thought, chose a subject in which he used mathematical methods in theological reasoning. The other two, though splendidly equipped in mathematics, preferred to present phases of physics. Our program shows six subdivisions of science, among which mathematics has always held a secure place, but up to the present time no one has had the inclination or the courage to attempt to discuss in a popular manner the oldest science and the one second to none in its services to mankind and in the zeal with which it is to-day cultivated and enlarged. It is, I confess, with misgivings that I break this thirteen years' silence, for the range of the subject has now become so vast that no one person can longer hope for an intimate acquaintance with all of it, and any writer must rely more or less on testimony for many results and their bearings upon progress. And yet when we consider the extent to which the science of mathematics is cultivated among educated people, the large part that it plays in all our lives, are we not justified in an occasional attempt to call attention to prominent facts concerning it as they appear to some of us who have spent fifteen years or more in trying to disseminate its truths?

In the British Association there have been at least three notable presentations of the claims of mathematics by three of its most famous exponents. One of these is little less than an inspired plea for his loved discipline, by one of its prophets; a second shows how higher ranges of the subject have been suggested by other sciences; a third is a classic argument for the unrestricted development of mathematics along systematic lines both for its own sake and for its possible future utility in fields now undreamed of. In the American Association there has been a tendency to make mathematical lectures more technical and therefore less interesting to the general public than in the British. One essayist made a notable attempt to explain modern algebra to the uninitiated, a second spoke upon the evolution of algebra, while a third gave a historical disquisition upon the origin of our methods with imaginaries. A fourth was an exception to these in that he argued for reform in the choice of subjects in college curricula and in the manner of presenting them.

The essential difficulty in discussing a mathematical topic is the fact that this science possesses the most highly developed symbolism and an almost perfect technical language. Both these attributes condense our reasoning to a minimum and make it unintelligible to the uninitiated. In trying to popularize, we are in danger of becoming puerile. Most mathe-

maticians of our time have abandoned the former attempt, and therefore speak a language absolutely without meaning to the average man. Often the use of symbols and technical terms is not even a matter of choice. It is a necessity, for the ideas sought to be conveyed can be expressed in no other language. The mathematician, therefore, often labors on with no understanding or appreciation of his work or its results on the part of the general public. His subject is dumped into the same class with the dead languages. Latin, Greek and mathematics must form an unnatural alliance in a fight for recognition. Too frequently the mathematician is grudgingly given but a tithe of what he claims, and even then he is asked why he should cumber the ground and impede the way to higher and more useful pursuits. Before Latin had a literature, mathematics *was*. Now, when the conviction is rapidly gaining ground and in all progressive institutions being put into practice, that a smattering of Greek and Latin soon forgotten are not essentials in education, mathematics have entered new fields and conquered new territory. Their cultivation has gone forward in the last generation in leaps and bounds, their advance has kept pace with and in a large measure conditioned, both on the material and intellectual side, the tremendous and unexampled progress of civilization in that period.

There are three general aspects in which mathematics can be viewed:

First. As a disciplinary study.
Second. As a cult.
Third. As a tool.

These three general grounds for consuming time and effort in cultivating this science are not mutually exclusive. Their territory frequently overlaps and the determination of the stronger incentive often depends upon the point of view of the individual or his environment.

As a disciplinary study, mathematics are present in some form in all the curricula of colleges, high schools and the grades. In the grades, however, we must recognize as the principal reason for time and effort, the thorough mastery of number and the development through drawing of the form perception for the practical every-day business of life's activities. At this point it has seemed to me that a serious error is quite commonly committed. Too often instructors imbued with that philosophy of education which unduly idealizes every subject taught, make a premature attempt to develop logical processes at the expense of an intimate knowl-

edge of number combinations and of a practical facility in their rapid and accurate manipulation. Very properly in the high school the disciplinary idea predominates, but even here it is a question whether the time is not near at hand when some of the older mathematical subjects taught should be in a measure set aside and other newer ones substituted which are of equal disciplinary value, but whose knowledge content is greater.

In the earlier portion of the college course the disciplinary idea still strongly predominates, but if mathematical study is continued through the last two years and into graduate work it becomes a cult or a profession or a necessary adjunct to a profession.

In its development we may roughly divide mathematics into three general subjects:

Arithmetic.
Geometry.
Algebra.

Yet again these, especially in their higher ranges, continually overlap each other. The theory of numbers seems to belong to arithmetic, yet some of the problems like that of prime numbers, which were among the earliest propounded, demand now for their approximate solution, after twenty-five centuries of development, the highest powers of analysis. In analytics, geometry and algebra melt into each other, while in the modern group theory the three which in their earlier manifestations seem so diverse in spirit and purpose form one grand generalization.

As a discipline these studies need no apology. Their influence in the development of the reasoning powers is unquestioned. They exercise the muscles and sharpen the teeth of the logical faculty. They furnish the growing mind with exercise in useful knowledge with reference to which it can have absolutely no prejudice and, while leading to certain truth, generate confidence in intellectual powers. They develop the inventive faculty by sharpening the powers of comparison, by diversifying and enriching the powers of attack, by developing the power of long continued attention and concentration.

As a cult, pursued for its own sake, it furnishes one of the highest occupations of the intellect. The mind revels in the realm of pure thought, and each triumph must bring the thinker closer to that all-pervading intelligence whose very existence and activity entirely removed from chance and imperfect knowledge must be conditioned by mathematical necessity.

The chemist often pursues his investigations into the constitution of matter without any thought of any possible utility in his results. He pursues the science for the sake of science, that man may grow in knowledge whether or not he can turn that knowledge to practical account in the manufacture of steel or the dyeing of silk or the synthesis of nitrogenous compounds.

Yet not seldom in his case, as in the history of pure mathematics, has it transpired that a truth sought for truth's sake has become the necessary foundation for splendid material achievement. One need but recall the labors of an Archimedes or a Newton to note how a searcher for higher mathematical truth for its own sake may become an epoch-maker in human progress.

It is not my purpose, however, to dwell upon this part of my subject, and I conclude with two quotations from Sylvester. In recommending the high living of the mathematician and nature's provision for his evolution he says: "The mathematician lives long and lives young; the wings of his soul do not early drop off, nor do his pores become clogged with the earthy particles blown from the dusty highways of vulgar life." And again: "Space is the Grand Continuum from which, as from an inexhaustible reservoir, all the fertilizing ideas of modern analysis are derived, and as Brindley, the engineer, once allowed before a parliamentary committee that, in his opinion, rivers were made to feed navigable canals, I feel almost tempted to say that one principal reason for the existence of space, or at least one principal function which it discharges, is that of feeding mathematical invention."

Passing, then, with this cursory mention, a theme so inspiring and fruitful as the consideration of mathematics from the ground of discipline and culture, let us confine our attention to the question of utility alone. What has mathematics done that it should commend itself to the great, struggling masses of humanity who are busily engaged in adding to the surplus products of the race, who are breaking the virgin sod or swinging the artisan's hammer or directing the world's exchanges? Has mathematics any right to stand with physics, chemistry, botany, zoölogy, geology, whose cultivation has revolutionized civilized life?

Can a science which begins with assumptions never in perfect accord with fact and which ends with conclusions impossible of exact application ever get its feet on the ground sufficiently to secure a leverage for pushing along the car of progress?

In considering the services of mathematics from this purely utilitarian point of view we shall find it convenient to speak of

GEOMETRY AND ANALYSIS.

The American people are unusually intelligent, but is it not true that no more than one per cent. of them ever have any adequate conception of the innumerable ways in which geometry enters into their every-day life?

Houses of all kinds, from the humble cottage to the Manufacturers' Building of the White City, from the backwoods meeting house to the vaulted cathedral, first grow on paper under the magic of geometry. Bridges and everything that rolls over them, shops and every manufactured product that comes out of them, grew into being in the same way.

Only a Michael Angelo can hew out a statue without model or drawing, but Raphael himself must resort to mathematical perspective for depth and sky. Not of Euclid do the towering buildings and the diversified industries of a teeming city attest, so much as they do of the Frenchman Monge, upon whose discoveries and researches are based our systems of industrial drawing now so rapidly and deservedly gaining ground. The time, I believe, is not remote when descriptive geometry in some of its phases will find a more open way into the high school and will insist on recognition whatever else may suffer. The heart of the shop is the draughting room, a room without which the trunk line, the ocean steamship and a thousand and one things necessary to our complex civilization can not exist.

The educational revolt of a generation ago against fossilized methods then widely practiced arose from a conviction that we had outgrown monastic institutions. The training suitable for a state of society where all education was in the hands of the church and all educated men became priests was found to be no longer adequate to the needs of a country which was rapidly developing into the most powerful nation on the earth through the industry, inventive genius and mechanical skill of its people.

The learning of the college was laughed to scorn. Then came science and elective courses, but this was not enough. Technology was transplanted from Russia and Germany. It took quick root and has had a marvelous growth in American soil.

Throughout the world what an expansion! till to-day, through the influence of their technical institutions of all classes, the civilized nations are battling for the industrial supremacy of the earth.

So essential is modern geometry to technology that it is safe to say the latter can not exist without the former. Through geometry the controlling mind translates the creative idea to the willing worker, and what was only a dream of beauty or utility now stands clothed in material form under the eye of the world for its edification, elevation and use. The artist whose masterpieces adorn our walls, first groups his figures as he wishes them to appear, then he calls geometry to his assistance to make them seem to be where he wishes them.

We mistake, however, if we confine the services of geometry to technology. Nature is continually inviting the observant mind to geometric study. The beautiful crystalline forms which abound in the rocks of the globe, in the snow and the ice speak of unity in infinite diversity. Under the microscope the thinnest plate of shapeless rock, the very particles of dust at our feet, tell through shape alone a story of origin and character interesting and valuable alike to the physicist, the geologist, and the chemist. The latter, interested in the ultimate forms of matter, finds suggestions for valuable theories upon atomic forms, and constructs geometric molecules in which a dissimilar position of a characteristic atom will in a measure explain such curiosities in nature as right and left-handed sugar, which, though having different properties, still are made of precisely the same constituents in the same proportions.

Analytic geometry occupies the border land between geometry and the higher analysis. The elements of this subject so far as the construction of loci is concerned are rapidly becoming the possession of the reading public. The variations of temperature, of humidity, of productivity, of commerce, of population, of crime and of the price of wheat, from hour to hour, or from day to day, or from season to season, are immediately expressed to the eye by curves in which portions of time are the horizontal measurements and the various values of the function are the vertical. In science the natural way to express one series of facts dependent on another is through a curve. Passing on from loci, which are so full of meaning and so suggestive of causal relations, it is customary to discuss in detail the circle, the parabola, the ellipse and the hyperbola. The laws of gravity lead to these curves, and they are the fundamental orbits of the bodies of the universe. In terrestrial matters they lie at the

basis of the laws governing stresses and strains, the study of optics, the propagation of impulses in homogeneous media, and a thousand practical things. As we rise higher and approach analysis we trace the lines along which stresses are propagated and materialize these in the beautiful iron bridge, with its parts nicely shaped and adjusted to the load it is to carry. Advancing further, our lines become in the strain diagram a veritable graphical calculus, through which we discover the stress with which any load, fixed or moving, strains a structure, and therefore through it find a ready means of designing our creations to resist safely the stresses to which they will be subjected.

But this brings us to the question of analysis—the other side of our subject. I shall not dwell upon algebra as we usually understand that term in high school and elementary college work. I need only speak of it as generalized arithmetic to recall to you how it gathers up the rules of the lower subject and condenses and generalizes them, and how, by introducing the result sought at the beginning of a series of operations, we easily carry to a conclusion logical sequences, otherwise exceedingly difficult to follow, and ascertain whether or not the problem proposed is capable of solution.

It must be confessed, however, that algebra in the ordinary school sense is very largely a discipline, little used in the ordinary affairs of life and finding its principal utility in the studies which lie beyond. Yet to pursue these with ease and success, a knowledge of ordinary algebraic methods and facility in algebraic manipulation, including the analysis of the angle, is a prime requisite. I come now to speak of the higher analysis in the sense in which it is ordinarily applied—that is, the infinitesimal calculus and its developments and allied subjects—the invention of which marks an epoch in human progress second, I believe, to no other scientific event.

It is curious, when we think back over human advancement, that some of the things now most patent to our senses escaped recognition so long. The alchemist stumbled through centuries without learning the nature of air and water. The most puerile ideas regarding the earth's structure prevailed down to the American Revolution and later. And so, while arithmetic, Euclid, Diophantine analysis and trigonometry are highly artificial, calculus brings us back to nature. Space and time were continually thrusting themselves upon the attention of man, motion in the former, rate in the latter, as exemplified by every moving thing and

changing substance, and were perpetually inviting attention to an arithmetic that took hold upon continuous number and rate of change. Yet for centuries without result. The method of exhaustions came very near to the invention of the calculus, yet Grecian civilization, with its brilliant record, flourished and died without any knowledge of it. A Scotch professor in Dalhousie University was accustomed to say that with the calculus the Greeks would easily have outstripped us in invention. In depth and clearness of thought, in majesty, beauty and originality of ideas and ideals, in strength and suppleness of limb and delicacy of touch, they were clearly our masters. They could geometrize amazingly, but they had no science of continuous number; therefore modern civilization is passing theirs with giant strides.

When the Reformation occurred in Germany, its spirit was abroad everywhere. Had Luther not come to the leadership at that time, who will say that another champion would not have arisen to espouse the new ideas and stake his life upon their success?

So, in the intellectual progress of the seventeenth century, new notions had permeated the mathematical world. The idea of the dependent and the independent variable had gained such ground that the then new science, analytic geometry, was the necessary result. This new subject lent itself readily to the graphic representation of mathematical interdependence and thus furnished in mathematical form a generalized expression and representation for a thing changing in obedience to law. The rate of change necessarily followed soon after, and isolated cases of its use in determining the tangent to a curve show that it was in the air. Newton and Leibnitz immortalized themselves by noting the mathematical drift, seizing the new methods and constructing from them the new discipline.

Thus man came into possession of an instrument adapted to discover and establish the laws and processes of nature because it is constructed on nature's model. Trees do not increase instantly a foot in height and then rest for a period before the next jump. Rivers are not at one instant a swelling, muddy flood, and at the next a clear, tranquil stream. The Knickerbocker Express does not go by jerks and instantaneous leaps from point to point as it passes over the space between Indianapolis and New York. But everything from external nature to the innermost soul of man connect various times, seasons and conditions by continuous num-

ber. The tree, the animal grows, the flood abates, the train progresses, mind matures, life expands, love deepens and broadens.

> " Chance and change are busy ever,
> Man decays and ages move."

God alone changeth not.

But everything we see, all else we can think of, is in a state of flux. The rate of these changes is matter of common observation and comment, and it is nothing but the first differential coefficient. Tait says every one uses the ideas of the calculus if he is not a fool. I doubt whether any of us, without we consciously give ourselves to reflection upon the subject, begin to see the clearness, the depth, the breadth, the comprehensiveness, of Newton's philosophic vision when he gave to the world the words *fluent* and *fluxion* in connection with his new culture.

As calculus was the first master-word spoken to the very soul of nature, so it has wrested from her first this secret then that, until man with this powerful ally is rapidly enslaving all her powers to work out his own will.

The calculus rewarded its discoverer by giving him the demonstration of the invisible chains binding the moon to the earth and then by delivering into his hand the secret of the system of the world. Who will estimate the services to civilization of these cosmical studies? Old superstitions disappeared forever. A man's horoscope became only a poetic fancy. Men no longer prayed to be delivered from the flesh, the devil and the comet. But our solar system was reduced to order and beauty, while mathematical analysis reached out with her long, delicate, quivering fingers and snatched from the depths of space a new planet—never seen by the unaided eye of man—to enrich the retinue of our sun, and to demonstrate the divinity of the human intellect.

This was the first great conquest of the calculus. But when it was turned upon things terrestrial, it exerted an influence less dazzling perhaps, but no less profound. It laid the foundations, more perhaps than any other one thing, for our age of brilliant invention and startling discovery. Great generalizations have sprung from active imagination and patient accumulation of facts. But these usually have a far richer content than their first announcers dream of. The calculus analyzes these great thoughts, recombines them and produces results the most unexpected and important.

Much of our polite learning has been in the possession of the world for two thousand years or more, but the peculiarity of our present civilization is the general diffusion of knowledge and the triumphs of engineering skill. Invention and machinery have multiplied man-power by twenty. And below it all lies the calculus. The successful engineer who would be anything but a mere slavish copyist must have a mind well founded in mathematics.

Let us refer briefly to some of the things which calculus has done or helped to do in engineering. We may say with little danger of contradiction that the engineering of to-day is a question of minimum causes and maximum effects—a question of the first differential coefficient.

A Tay bridge disaster reveals a crime against humanity. We wonder at the pyramids and temples of Egypt, but when we think of the lives sacrificed like flies in these colossal but useless works, where the means employed were vastly out of proportion to the ends sought, here, too, was a crime against humanity.

It is equally beneath the dignity of the disciplined man to put too much or too little into a structure to serve its designed purpose in use and beauty.

In hydraulics, calculus investigates water pressure on a submerged surface and center of pressure for same, thus determining the size and form of retaining walls of all kinds, and solving the first problem of a water supply. It also investigates the quantity of discharge through orifices, notches and overweirs, determines the most economical sections of conduits and canals, the time of emptying or filling locks or other vessels under a varying head; the maximum range of jets from a given inclination determines empirical formulae from experimental data by the aid of least squares; discusses non-uniform flow in rivers and back water curve above dams; discusses the maximum work derived from moving vanes, such as stationary water wheels, wheels of steam boats, and screws of propellers.

Fifty years ago an excellent engineer by the name of Uriah Boyden spent weeks in designing the buckets of a water wheel. He obtained correct forms, but by the aid of the calculus a man no more talented naturally may to-day do the same work in two or three hours.

In machinery and structures it investigates the work absorbed by friction of pivots and the like; moments of inertia and centers of gravity

leading to transverse strength of beams, their deflections, slopes and elastic curves; it establishes the strength of thick hollow cylinders and spheres upon which is based the design of fire-arms and ordnance; computes suspension bridges: determines stresses in arched ribs of iron, steel, or timber, or in stone arches.

It gives the mathematical theory of maps, derives formulae for computing geographical co-ordinates and for map projection; adjusts observations in triangulation and determines the probable error.

It analyzes and improves the steam engine; it studies the effects of reciprocating parts, studies the balance wheel, the shaft, rods, and cranks; it enters the steam box and discusses steam pressure, horse power, and efficiency. It measures the contents of irregularly shaped vessels.

It may sometimes seem that the problems along these lines have been worked out and embodied in the shape of formulae and that there is no more use to study the method further for these purposes. That, however, is not true. A man should always be master of the tools he is using if he wishes the best results. The man who can derive a formula understands best its applications and limitations. Moreover, occasionally new and important questions arise which can not be answered at all unless one is versed in the use of the calculus.

It has largely developed the dynamo and has given us Fourier's series upon which the theory of this machine rests.

Klein once said to a former pupil of his:

"You know that I have been too busy with theoretical matters to keep up with the practical things; what is the greatest recent discovery in the application of electricity to the arts?" The pupil replied: "The greatest recent discovery in electrical engineering is a method by which a current may leave a long circuit at a higher potential than it entered it." This is the well-known principle by which Niagara Falls, for example, becomes available many miles away from the fall itself, as a source of power. Klein said: "Wait. That," he presently exclaimed, "depends on the second differential coefficient."

Problems such as I have thus far alluded to are the problems of civilization. Light, heat, power, architecture, water supply and distribution, dissemination of news, transportation—did you ever think how closely these things affect us? Chemistry and mathematics have done their best in providing for our locomotive a rail that would resist the strain of a

40-ton car and an 80-ton engine. The 40-ton car is the ship of the plains. Without it millions of acres now dotted by happy homes would have been unavailable for settlement.

Up to this time but a small per cent. even of our educated people have been imbued with the spirit of the calculus and have appreciated its power. Indications point to a large expansion in the near future in the number of those who will cultivate it for the power that it will give.

A popular German treatise upon this subject has recently been written expressly for chemists.

The object of this treatise is easily deduced from a remark in it quoted from Jahn in his elements of electro-chemistry. He says: "Chemists must gradually accustom themselves to the thought that theoretical chemistry without the mastery of the elements of the higher analysis will remain for them a sealed book. For the chemist the differential or integral sign must cease to be a senseless hieroglyphic if he will avoid the danger of losing all comprehension of the theory of his subject. for it is fruitless labor to attempt to make clear in many weary pages what an equation says to the initiated in a single line."

By the higher analysis Guldberg and Waage have obtained formulae for studying the course and end of a chemical reaction. Neither in the application of analysis to chemistry are mathematical difficulties seriously in the way. The inner nature of the physical or chemical process is represented as truly by the method and working of the higher analysis as an object is represented by its photograph.

The power of the analysis in nature lies largely in its ability to deduce instantly from one set of laws another set equally important which at first sight do not seem to be closely related to it. For example, knowing the law of motion in space, we deduce velocity at any instant; knowing the chemical reaction as a whole, we deduce its intensity at any moment; from the weight of air and the law of gases we deduce its pressure at any height.

To the chemist we must look for the solution of many problems, whether of theory or practice. Perhaps the greatest of these is *the* philosophic question of the ages—*the nature of matter.* If this question is ever definitely settled it will be by the chemist, with the aid of the calculus.

The higher analysis in its services to mankind is not confined to the exact sciences.

Those who cultivate the natural sciences, so called, have been making and sifting vast accumulations of important facts with an enthusiasm, energy, patience and self-devotion which form an impressive illustration of the self-denial, the intelligent consecration of self to the race, the sublime purpose in life of the educated man of to-day. Where in history will you find finer examples of chivalric self-renunciation than are occurring among these men and women every day? Natural history has had its profound generalization. From the nature of the scientific laws of the origin of species, and from their fancied bearing upon religion as well as science, every foot of ground has been bitterly contested. Even to-day Darwinianism has many confident enemies. The controversy has reached that stage, however, where something akin to mathematical demonstration is needed if the theory would make further serious advance. To this last chapter Indiana is worthily making its contribution; but when an attempt is made to discuss observations and establish results upon higher ground, the calculus again comes into requisition. Indeed, so should it be, as the problem here presented is simply this: Can small accidental variation be integrated into specific differences?

Geology in its dynamical aspects, in its discussions of the earth's interior, and in questions of time necessary for the deposition of strata under varying conditions must sooner or later resort to the infinitesimal analysis.

To these will be added surface problems similar perhaps to the one suggested by a geologist. He asked that the calculus should be applied to determine the way in which varying temperatures apart from rain or frost may round off angular fragments of rock.

As political economy grows in certainty and increases in exactness, it is found that it becomes a proper field for the higher analysis. Economists, in fact, who desire to get the full content from the material which they try to interpret and generalize are coming to the calculus for an essential part of their equipment. In 1838 Augustin Carnot wrote upon the mathematical principles of the theory of wealth. Recently this has been translated in America, and a Yale professor has published a little work on the calculus to enable those to understand it who are untrained in higher mathematics. In all products which may freely invite competition there are certain ascertainable relations among quantity, demand, price and profit. These are expressible in analytic form, can be operated

upon by the methods of the higher analysis and the result can be reduced to rational laws for the control of trade.

When the diversified interests of our country have been thus subjected for a period of years to statistical investigation and these results again have been formulated into equations of condition which in turn may be operated upon by the prolific methods of the mathematician; when finally the laws thus deduced have been published, read and understood, we may hope that commerce may be something besides a shrewd guess and that its shores will not be strewed with the wrecks of the hopes of 95 per cent. of those who embark upon its uncertain tides.

In 1815, Elkanah Watson, the well-known promoter of the Erie Canal, made his famous prophecy concerning the rapidity of the settlement of the United States. Some will remember how marvelously accurate this prophecy was fulfilled up to the sixth decade. But, beginning with the census for 1870, a wide divergence set in. At first the large deficiency in the observed population of 1870 was naturally attributed to the influence of the civil war. The mathematicians, however, soon began to analyze the returns and they discovered that the havoc and distress of our great conflict was quite inadequate to account for the change in rate of increase. As a result of these purely mathematical investigations, our sociologists began to search for the new conditions which were so profoundly affecting American life. They found them in the increase of luxury, in the more expensive habits of living then introduced, which tended to check the size of American families. So, analysis applied to sociological questions can not report on more forces than have been entrusted to it, but it may call attention to the fact that new and unknown causes have entered into problems under discussion and show where they first made their appearance. Thus it may lead the way to discoveries of vast moment in the sum total of human knowledge.

To what is our analysis leading us? Who can tell? It is certainly gradually arming us with powers comparable to those of the fabled Martians of recent Cosmopolitan fame.

Faraday was probably an abler man than Maxwell. The former developed many ideas which would not have occurred to the latter, but he was no mathematician. Maxwell took up the results furnished by his predecessor and worked out by the calculus the electro-magnetic theory of light, deducing many curious things which could never have occurred to Faraday.

Our warrior no longer wears mail and carries the cumbrous shield, spear, and battle ax, but we arm him with the Krag-Jorgensen and he strikes his blow from as far away as he can see his man. .

Who will set the limits to our advance? As our knowledge becomes more exact, the application of our analysis will widen till it embraces man and nature in all their essence and relations.

WOOLLEN'S GARDEN OF BIRDS AND BOTANY. BY W. W. WOOLLEN.

Woollen's Garden of Birds and Botany is situated due northeast from the city of Indianapolis, on the south bank of Fall Creek, and is nine miles from the Indiana Soldiers' Monument, the center of the city, and four and a half miles from its corporate limit. It consists of forty-four acres of land, being four acres larger than Shaw's Garden, near the city of St. Louis. About twenty-nine acres of the garden is woodland, and the remaining fifteen acres are in cultivation.

It has a river front of one-third of a mile, and this is covered with timber and vines. The cultivated portion, most of which is rich bottom land, lies between the river front and the woodland. This is divided by strips of timber into three irregular parts and susceptible of being made very useful and attractive. In it, with little expense, two lagoons can easily be made for the growing of water plants. The river front can be admirably adapted to the same use.

The timber land consists of three hills, extending from the south to the north, the projections of which gracefully slope to the cultivated land, forming two perfect amphitheaters overlooking the cultivated land. These amphitheaters are exceedingly beautiful, the line of timber on them coming down to the very edge of the cultivated land and encircling it on the north with curved lines as true as could be drawn by a landscape gardener.

The hills are from one hundred to one hundred and twenty-five feet high, and divided by spring rivulets, which have rocky bottoms and beautiful meanderings. On one of these hills, in the very depths of the forest, is an immense bowlder, and on another a very considerable mound, which tradition says is the grave of an Indian chief. None of the hillsides are precipitous, and because of this, every inch of their surface is adapted to

the growing of something, and in fact is covered with wild plants. On the projection of one of these hills are to be found more hepaticas and trilliums than at any other place in this section of the country, and on one of the hillsides about three-fourths of an acre is covered like a meadow with celandine poppies.

The native wild plants have never been disturbed in this piece of forest, it having never been pastured, and here I have found growing a greater variety of trees, shrubs, vines, herbaceous plants and fungi than in any other place that I have seen in all the tramping that I have done, and I have been a tramp all of my life. No amount of money or labor that could be expended by man could make such a garden as has here already been created by God. Truly, it has been written: "The heavens declare the glory of God, and the firmament showeth His handiwork." "His works are done in truth;" "the earth is full of the goodness of the Lord."

The primary idea I have in mind is to preserve these "wondrous works," just as they are, for all time to come. My second thought is that to this garden shall be brought, planted and preserved every tree, shrub, vine and plant not already growing in it, which now grows, or has heretofore grown, in Indiana; in other words, that the garden shall represent the botany of Indiana.

Of the birds it is written, "and not one of them is forgotten before God." Then, why not we have considerate care for them? Again, it is written: "Yea, the sparrow hath found an house, and the swallow a nest for herself, where she may lay her young." This embodies my thought as to what the garden is to be for the birds. That is, that it is to be their home, and a place where they can have their nests and raise their young without molestation. The garden is peculiarly favorable for both land and water fowls, and every effort will be made to make it a favorable stopping and breeding place for them. In doing this, special attention will be given to the planting of trees, shrubs and vines that produce fruits, berries and nuts, so that they, the squirrels and the like, may have plenty of food.

My hope is that provision may be made for a library and appliances for the study of natural history, in connection with the garden, and that the whole may be in charge of a curator.

I was born in the city of Indianapolis; what little college education I have was obtained at Butler College, and the Indiana Academy of Science

has honored me with membership in it. And so I have it in mind to vest the title to the garden in the city of Indianapolis, and when I have done with it, to place it under the control of the Superintendent of the Schools of Indianapolis, the President of Butler College and the President of the Indiana Academy of Science for the joint benefit and use of the bodies represented by them. In doing this, I expect to have the hearty support of these bodies, and the labor and pleasure of developing the garden shared by them.

At my time of life and with my limited means, I can not hope to do more than to get the garden fairly under headway. I have, however, an abiding faith that ultimately it will become "a beautiful book of living nature."

Plans for the New Buildings of the Biological Station.

By Carl H. Eigenmann.

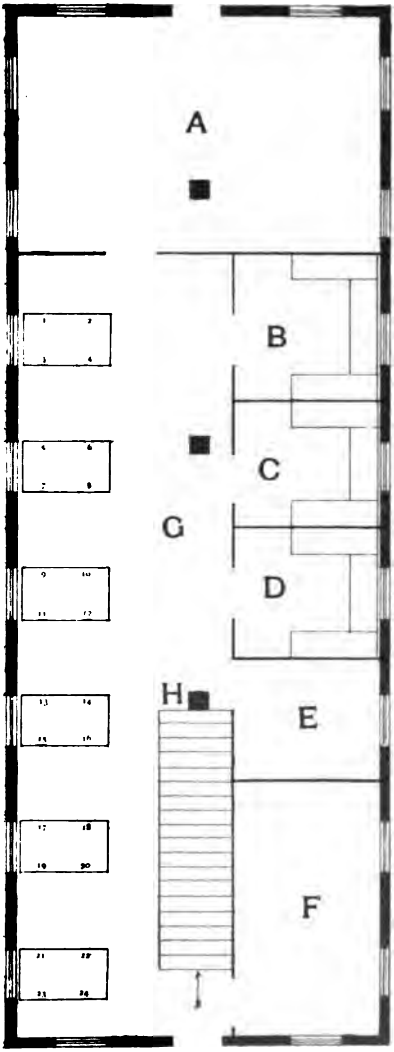
The Indiana University Biological Station, established on Turkey Lake in 1895, will be moved to Eagle Lake (Winona Lake), eighteen miles from its present location. Buildings will be erected by the Winona Assembly and Summer School Association after the plans 1, 2, 3 and 4.

Plan 1. Lower floor of the zoological building.

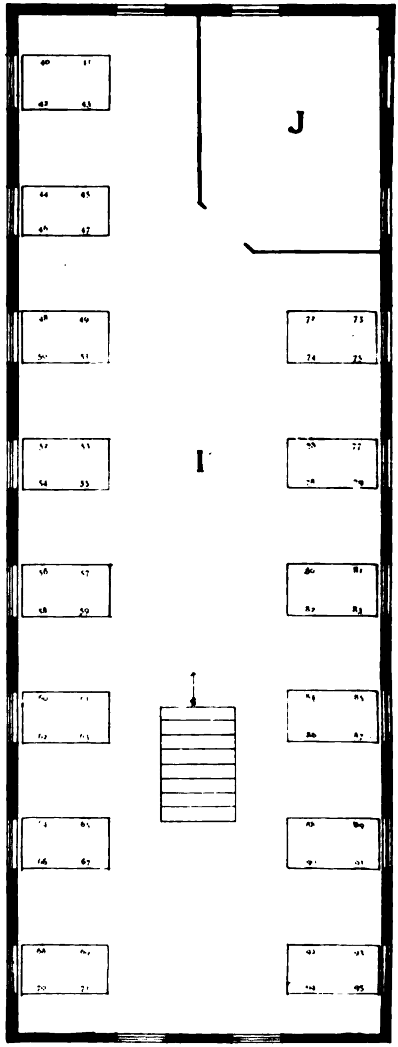
- (a) Director's office.
- (b) Private laboratory.
- (c) Private laboratory. Assistant in charge of the building.
- (d) Private laboratory. Dr. Dennis.
- (e) Photographic room.
- (f) Assistants' room.
- (g) Lake survey laboratory.
- (h) Dark room under the stairs.

Plan 2. Second floor of the zoological building.

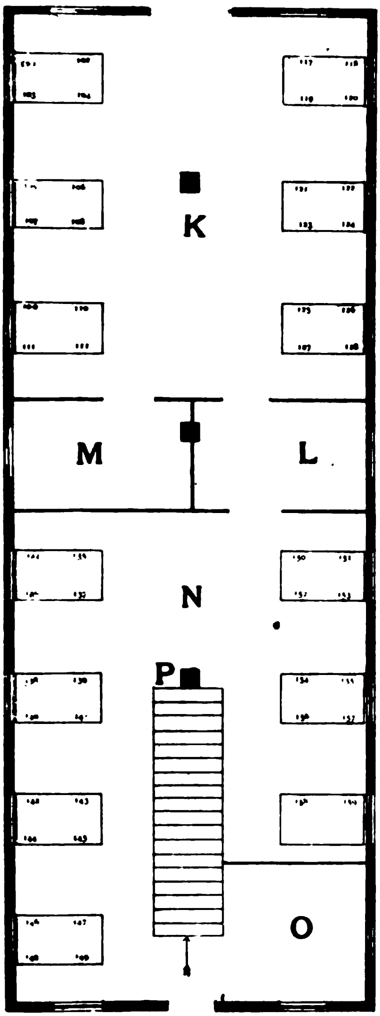
- (i) General zoological laboratory.
- (j) Dr. Slonaker's private laboratory.



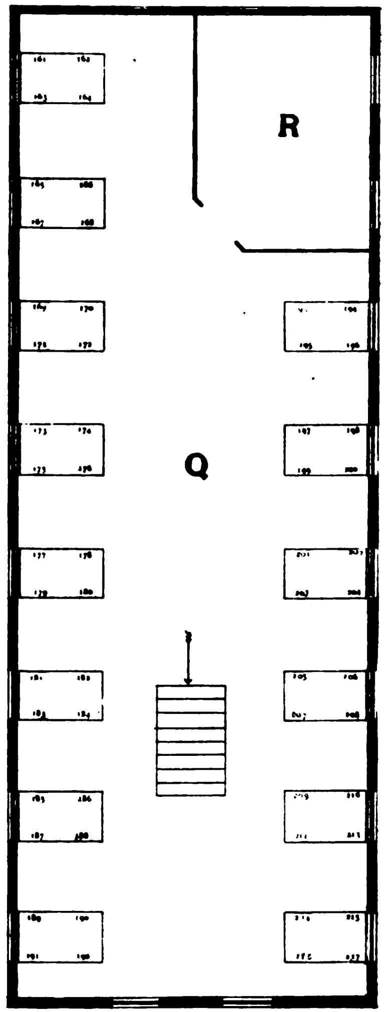
Plan 1.—Lower Floor of Zoological Building.



Plan 2.—Second Floor of Zoological Building.



Plan 3.—Lower Floor of Botanical Building.



Plan 4.—Second Floor of Botanical Building.

Plan 3. Lower floor of the botanical building.

(k) Embryological laboratory.

(l) Microtomes.

(m) Assistants in charge of the building.

(n) Bacteriological laboratory.

(o) Dr. Lyons's private laboratory.

(p) Dark room.

Plan 4. Second floor of the botanical building.

(q) General laboratory.

(r) Dr. Mottier's private laboratory.

Slight modifications may be made in these plans during the construction of these buildings. They will be ready for occupation June 1. 1899.

Explorations in the Caves of Missouri and Kentucky.

By Carl H. Eigenmann.

Through a grant of $100 from the Elizabeth Thompson Science Fund and the liberality of the Monon, Louisville & Nashville, Louisville, Evansville & St. Louis, and St. Louis & San Francisco railroad companies, I have been able to put two short vacations to the best use possible. The first week in September was spent in southwestern Missouri and the southeastern part of Kansas.

While much incidental information was gathered concerning caves and cave animals, the chief work of the trip was to visit Marble Cave in Stone County, Rock House Cave in Barry County, Spring, Day's, Wilson's, and Carter's caves in Jasper County, and a cave whose name I have lost, east of Springfield in Green County, Missouri. The actual results were obtained in Marble Cave, Rock House Cave and Day's Cave.

To reach Marble Cave it was necessary to travel nearly forty miles from the railroad over a rough country well deserving the name of Stone County, for in some places it was a speculation where the inhabitants were able to secure mud enough to stop the chinks in their log houses. Marble Cave opens at the top of a hill that is, I was told, 675 feet above White River, a short distance away. The entrance leads down over a winding stairway and around a pile of fallen debris for over a hundred

feet. The object in quest of which I came to this place was the very rare cave salamander, Typhlotriton. It was found in a low passage, so low that going on hands and knees was in many places out of the question. The process of going snake fashion was facilitated by the slippery roof, and, in many places, a muddy floor. A layer of water of varying depth covered the floor. In this water, under rocks, I found the salamanders. It is worth pondering that here, many feet under ground, this salamander has retained the retiring habits of its confreres of the upper surface. I secured four adults and two larvae at this point. One of the adults I met coming down a slippery slope on all fours, while I was going up in the same fashion.

Rock House Cave is reached from Exeter on the Frisco line by a little railroad that runs down hill all the way to Cassville, and thence by buggy to Rock House Cave. Evidently there formerly was an extensive series of underground streams here. The main cave has been obliterated by erosion, which has cut down below the former level of the main cave. As a result we find here a deep, narrow valley with small tributaries emptying into it from caves opening high up on the sides of the valley in little gorges. The largest of these is Rock House Cave, with an entrance large enough to serve as a carriage house. In the gravel of the bed of the small rivulet coming from this cave I secured an additional lot of larval Typhlotriton, but could find no more adults. This cave I entered twice by myself.

Day's Cave I had visited a year before when I sat, lamenting and in impotent rage, at the mouth of this hole in the ground. It was full of water, the mouth choked up and I could not get in. Now I came with plans for excavations which I would set on foot while I went elsewhere to look for game. To my delight I found that some enterprising citizens had dug a neat passageway into this cave to see what could be done with the water to supply the town of Sarcoxie. It was still necessary to crawl to get in, but I was at once rewarded, for I caught the new genus of blind fish described in the proceedings of this Academy last year as Typhlichthys rosae. I entered this cave twice in one day and secured eight fishes.

I was induced to go on a fool's errand into Kansas by the things described by an old miner with a string of scintillating expletives as being common in the drifts of the extensive mines of that region. But aside from a little experience nothing was gained on this trip.

On November 22d, I started for Mammoth Cave. The objects I especially wanted were the very rare Chologaster agassizii, specimens of Amblyopsis from south of the Ohio, Typhlichthys subterraneus and the cave rat, Neotoma. Mr. H. C. Ganter, manager of Mammoth Cave, did everything in his power to make my trip both successful and pleasant.

Although all the likely places were examined, not a single Typhlichthys or Amblyopsis could be found. After a day in searching for Chologaster, when almost despairing, we found, in a little pool of the river Styx, several of these very rare fishes lying on the bottom. As soon as my net touched the water they were off, and since the mud at the bottom was very easily riled but two specimens were secured. Next day the same spot was visited, when two more specimens were secured.

A horse-back ride of several miles brought us to Cedar Sinks. The roof of an enormous cavern has here fallen in ages ago. At one end the overarching rocks, which form part of the sides of this ancient dome, still bear witness to the existence of a former stupendous structure which covered several acres of ground. At the bottom of this cliff a few small openings lead into caves. One of these, judging from the strong current of air passing into it, must be a large cave. In these caves an additional specimen of Chologaster, the largest secured, was taken, and this repaid amply for all the trouble it had cost to come.

One cave rat was killed in Audubon Avenue in Mammoth Cave. An account of this rat, as well as of Chologaster, will appear elsewhere.

One other catch of great importance was made. I secured a specimen of Cambarus pellucidus with young. A good series of these has been preserved for future study.

A few words should be added about Mammoth Cave itself. I came to this cave the second time, regarding it simply as a locality harboring cave animals. Opportunities came to see much of the cave, and I must confess having become impressed with the value of the scientific problem the cave itself presents and the absorbing interest of its scenery. There are really four tiers of caves, one above the other. The upper two stories are dry, but the lowest contains water permanently. The present outlet of the cave is practically on a level with Green River at its low stage, and if the size of the cave increases it can only be by dissolving the bed rocks of the Echo and Styx Rivers. The water is said to rise sixty feet and more during heavy rains, the outlet of the cave streams being very small. The different levels of the cave are joined by direct channels, by

long and devious channels and by wells, some of which, like the Mammoth Dome, are 150 feet from top to bottom. The floor of the main cave is on the second level, while its roof is on a level with the roof of the fourth tier. We can easily imagine that when the Green River had cut through the sandstone overlying the limestone in which the cave has been formed, an outlet for water collecting in the crevices of the limestone was found near the present entrance of the cave. The main crevice developed into a large stream, cutting down and dissolving the rock much more quickly than its smaller tributaries. The tributaries fell into the main stream in little cascades and their floors, the present fourth level, remained permanently above the main cave or second level. As Green River cut through its limestone bed a lower exit was opened for the waters of this primeval mammoth river, and later still, a lower. By the formation of the pits and winding channels the water finally permanently abandoned the upper channels and is found now only in the lowermost levels. When this process began only aquatic animals could enter the cave. Even after the cave had become quite large it probably became full to the top during floods. This is still the case in many caves of Indiana. As a matter of course only aquatic animals were able permanently to establish themselves. But when the upper levels became permanently dry other animals could and did enter the caves and others are evidently still colonizing them.

The scenic parts which make the most lasting impression are Echo River, the Mammoth Dome and the main cave. The main cave is simply a very large winding tunnel, not startling in any way, but by the time one has walked for an hour or two it begins to impress one very forcibly. The Star Chamber and Martha Washington Statue, in this part of the cave, are remarkable in their way. The echo of Echo River lasts but twelve or fifteen seconds. It is remarkable for the blending of simple sounds, not for the repetition of words or phrases.

Notes on Indigestible Structures in Articles of a Vegetable Diet.

By John S. Wright.

Many articles of a vegetable diet, especially those which are consumed in a crude or raw state, contain tissue elements which pass through the alimentary canal without losing their identity. Examinations of fecal matter show that all of the tissue elements from parenchyma to sclerenchyma may under various conditions pass through the entire digestive tract almost unaltered so far as general character is concerned. In some diseases of children and in disorders of the digestive organs it is necessary to make fecal examinations to complete the diagnosis. In several such cases which have come to my knowledge the presence of these vegetable cells has given rise to considerable speculation, particularly where the physicians were not familiar with plant histology.

In one case the presence of what afterwards proved to be parts of orange pulp was very perplexing; in another the attending physician was concerned over the repeated occurrence in the stools of shredded or fibrous matter. As the patient, a man, was being treated for dyspepsia, he was of the opinion that these fibres resulted from the epithelial layer of the intestines. On submitting them for examination, they proved to consist wholly of tracheary tissue, mostly pitted vessels. In his examination, the physician had taken each pit to represent an animal cell. On inquiry it was learned that the patient, during the time his feces contained this material had eaten freely of small, fibrous sweet potatoes, which were likely the source of these pitted vessels. The above and other cases have suggested to me that further histological studies of the common articles of our vegetable diet would prove of practical value from both the medical and botanical standpoint.

The Action of Mercury and Amalgams on Aluminum.

By Geo. W. Benton.

Some Field Experiments with Formalin. By Mason B. Thomas.

At the last December meeting of the Academy we made a preliminary report on the effects of formalin on germinating seeds. As stated at that time, the experiments were conducted in the greenhouse, where all of the

conditions could be properly controlled and the best results secured. This work was intended to be preparatory to the field experiments to be tried early in the following spring.

The field experiments made with corn and oats were so striking that their results warrant publication and general application in the dealing with the smut of these two cereals. The laboratory experiments showed that the seeds of various plants would allow of only a special treatment with a certain definite strength of solution. The results of these tests gave us a basis for our field experiments and made this part of the work much easier.

The experiments of last year showed that wheat can safely be treated with a one-fourth per cent. solution of formalin for one-half hour, oats with a one-half per cent. solution for three hours and corn with a one-half per cent. solution for one hour, without interfering with their germinating powers.

The field experiments were tried with oats and corn on the farm of Mr. Henry Davidson near Whitesville, Ind. The oats to be treated were soaked for one-half hour in a one-half per cent. solution of formalin and then, without drying, sowed broadcast and the field dragged. Untreated seeds were sowed in a plat of ground alongside of these, and careful records made of the developments. The seeds in the two plats germinated at the same time and showed, so far as early appearances were concerned, no differences as a result of the treatment. The mature plants of the treated seeds were slightly smaller than those of the untreated ones, but the amount of grain produced was the same in both cases, except for the difference occasioned by the presence of the smut.

Upon ripening, the plants of the untreated seeds showed six per cent. of smutty heads, while none of the plants of the treated seeds had even a trace of smut about them, thus vindicating the value of formalin as a fungicidal agent.

In the experiments tried with corn, the seeds were soaked in a one per cent. solution for one hour and then dried in the sun. This treatment was more severe than that found advisable in the laboratory experiments. As a result the seeds were somewhat delayed in their germination and in some cases the plumule was not visible above the ground until two or three days after all of the untreated ones, planted in a corresponding plat alongside of these, had made their appearance. This inequality between the plants of the two plats was not of long duration and at maturity no

difference in size and development could be detected between the plants of the two plats. Of the plants from the untreated seeds two per cent. were attacked by the smut while none of those of the untreated seeds showed any signs of the fungus. These results with corn show the possibilities in this direction. Of course infection during the growth of the plant would not be prevented by this treatment. The treatment is not difficult. and the actual expense for the cost of material is not over six cents per acre.

Comments on the value of formalin as a fungicide are not necessary in view of the facts as presented.

Extensive arrangements are being made for experiments the coming spring on ground that has in years past produced crops showing a loss of from forty to sixty per cent. from smut.

The Resistance of Cereal Smuts to Formalin and Hot Water.

By William Stuart.

In connection with some studies on the comparative merits of formalin and hot water in the prevention of smut in wheat and oats. the subject of the resistance of the smut spores when treated separately was considered of sufficient importance to warrant investigation. The smuts of wheat and oats were selected from the fact that these two cereals are the only ones of economic importance in the State which it is possible to treat successfully for smut. While it is possible to kill the spores of corn smut by treating the seed, it affords no guaranty that the plants will be free from smut. This is owing to the fact that the method of infection by corn smut is unlike that of the other two cereals, inasmuch as the corn plant is liable to infection at any point where there is young, growing tissue, and at any stage of its development.

In order to test the relative resistance of smut spores as compared with the grain itself, separate lots of each were treated side by side in the same solution.

The smut spores used were those of the loose smut of wheat and oats. These were obtained from a quantity of smutted heads collected last summer from badly infected fields. When required for use the smutted por-

tions were removed and passed through a sieve to get rid of the coarse particles. The spores after being well mixed were collected in a box and formed a supply from which successive portions were taken as required for treatment.

In treating the smut spores and grain, considerable care was exercised in furnishing conditions which would insure similar treatment for all. This was especially necessary, as in the case of the hot water treatment it was found that in the high temperature treatments a difference of about five degrees occurred between the upper and lower surfaces of the water in a three-gallon bucket. To obviate any possibility of one lot receiving different treatment from that of another, especially when both were treated at the same time, the following method was adopted: The smut spores were enclosed in fine muslin sacks, weighted by tying a few grains of shot in the corner of them. The grain, about half an ounce being used, was put in loose muslin sacks, similarly weighted. The sacks were suspended on a rod, at a uniform level. When ready for treatment they were dropped into the solution, the weights instantly carrying the sacks below the surface, while the rod rested across the top of the vessel, thus holding them in place. The water at the level of the sacks was maintained at the desired temperature. In each instance the five and ten minute treatments were made at the same time, the removal of the former being readily done without in any way disturbing the remaining ones.

The treated spores were germinated in hanging drop cultures in moist Van Tieghem cells. Control cultures of untreated spores were mounted in the same manner. The spores were germinated in distilled water. Whenever any doubt existed in regard to the behavior of the cultures, fresh mounts were made. Cultures of the treated spores were made as soon as possible after their removal from the solution.

The grain was germinated in the laboratory in a Geneva germinator. As only a small quantity of seed was treated, but two hundred seeds were used in the germination experiments. The germinating seeds were counted and removed from the germinator each day until germination ceased.

The results of the work performed are given in Tables I. and II. It will be noticed that these do not include anything upon wheat smut. In explanation of this, the writer wishes to state that, at the beginning of the experiment, the germination of the wheat smut spores was very unsatisfactory; frequently none would germinate in the control cultures. As the

work progressed the viability of the spores decreased until practically none grew. Under these circumstances it was thought best not to present any of the data.

TABLE I.

Germination of Oat Seed and Smut Spores After Immersion in Formalin Solution.

Per Cent. of Formalin.	Length of Immersions.	Number of Spore Cultures.	Number of Cultures Showing Germination.	Per Cent. of Grain Germinated.
Control	....	12	12	99.5
One-fourth	15 min....	4	0	92
One-fourth	30 min....	4	0	93.5
One-fourth	1 hour....	4	0	90.5
One-fourth	2 hours...	2	0	95
One-half	15 min....	4	0	92.5
One-half	30 min....	2	0	91
One-half	1 hour....	2	0	91
One-half	2 hours...	2	0	86.5

As will be seen by Table I. but two strengths of formalin were used, these being a one-fourth and a one-half per cent. solution. These two strengths were chosen because they were considered sufficiently strong to prove effective against smut when it was immersed but a short time, and would therefore more nearly represent comparable conditions with hot water treatments. In these two solutions the grain and smut were immersed for periods of time varying from one-quarter to two hours, the intervening points being one-half and one hour, making in all four treatments.

Taking the shorter treatment by the weaker solution, it was found that even when a minute quantity of spores was treated, if they were mounted at once in a hanging drop culture, quite a large per cent. of the spores would germinate. If, on the other hand, the spores were allowed to remain in the sacks until dry and then mounted, no germination was

obtained. The same results were also obtained in the half-hour treatment, and not infrequently an occasional spore in the hour treatment.

Spores treated one-quarter hour in the one-half per cent. solution would show slight germination if cultures were made as soon as removed from the solution, but if allowed to become dry and then mounted no spores germinated. The longer periods of treatment gave no germination whether cultures were made at once or after the spores were allowed to become dry.

In the treatment of smut spores with formalin it was found that if what ordinarily might be called a small quantity of spores were taken very variable results were obtained. This seemed to be due to the imperviousness of the spores, when any number were collected together, to the formalin. This feature did not appear to enter into the hot water treatment, apparently they were not impervious to the hot water. Probably this was largely due to the somewhat oily properties of the formalin.

Another notable feature of the formalin was its action on the spores after their removal from the solution, and which in the shorter periods of treatment resulted in no germination of the spores, as against fair germination in those mounted as soon as removed from the solution.

The formalin used was that known to the trade as "Formaldehyde. Merck," a supposedly genuine forty per cent. formaldehyde solution.

Some indirect references have been found in regard to the action of formalin on smut spores. In one of these references the author[1] found that the spores of species of *Ustilago* and *Tilletia* were killed after treatment for two hours in a one-tenth per cent. solution of formalin. In a discussion following the presentation of the paper, Krüger stated that spores of *Ustilago carbo* were not killed by immersion for twenty-four hours in a .05 per cent. formalin solution.

E. A. de Schweinitz[2] says that a formalin solution of 1:10,000 has been recommended for destroying the spores of smut.

The effect of formalin upon germination of the seed was not very well marked. A slight injury was noticeable, but the percentage of germination was good.

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[1] Geuther; Ber. Pharm. Gesell., **5**: 325-330, 1895; Abs. in Chem. Centr. Bl., 1896; Abs. in Jahresb. Agr. Chem., **19**: 418; Abs. in Bull. Ind. Agr. Sta., **65**: 34; Abs. in Exp. Sta. Record, **9**: 569.

[2] Yearbook Dept. Agr., 259, 1896.

TABLE II.

Germination of Oat Seed and Smut Spores After Immersion in Hot Water.

Temperature of Water.	Length of Immersions.	Number of Spore Cultures.	Number of Cultures Showing Germination.	Per Cent. of Grain Germination.
Control	....	14	14	99.5
110° F.	5 min	2	2	....
110° F.	10 min	2	2	....
115° F.	5 min	2	2	....
115° F.	10 min	2	2	....
120° F.	5 min	4	3[1]	....
120° F.	10 min	4	0	....
125° F.	5 min	1	0	93.5
125° F.	10 min	2	0	94.5
130° F.	5 min	1	0	90.5
130° F.	10 min	1	0	88
135° F.	5 min	1	0	95
135° F.	10 min	1	0	93
140° F.	5 min	1	0	53
140° F.	10 min	1	0	42.5

In Table II. is presented the result of the hot water treatment, the range of temperature being from 110°—140° F. The lowest point of effectiveness was found to be 120° F. for ten minutes. This is a point at least ten degrees below the effective point of treatment of the grain for the prevention of smut[3]. The grain itself showed little injury from treatment at an increased temperature of fifteen degrees over the effective point for smut. The inference to be deduced from this fact is that in the hot water treatment there is quite a marked range in temperature between the limit of spore resistance and that of the resistance of the grain. The effectiveness of the treatment between these two limits would seem to depend wholly upon the ability of the operator to bring each seed in contact

[3] Arthur, Ind. Agr. Exp. Bull., 35: 86, 1891.

with the hot water a sufficient length of time to reach all the smut spores.

Of formalin it may be said that, although it is a comparatively new fungicidal and germicidal agent, it has nevertheless been employed to quite an extent in the prevention of parasitic diseases. So far as known it was first employed in this State by the botanical department of the Agricultural Experiment Station at Purdue during the winter of 1895-'96 in the treatment of scabby potato tubers for the prevention of the scab[4]. The treated tubers were grown in the greenhouse, and the resultant crop gave such satisfactory results that more extensive trials were made in the open field during the season of 1896. The results of these trials have been reported in the bulletin already cited.

Two experiment station bulletins are known to have been issued containing reports of trials with formalin for the prevention of wheat and oat smut. The first of these[5] reports the use of formalin in the treatment of wheat and oats. The author found a solution of one pound to fifty gallons to be effective when the seed was given a two-hour treatment. The other bulletin[6] referred to contains an account of the use of formalin for the prevention of smut in oats. It was found that smut spores were destroyed by immersing the seed two hours in a 0.2 per cent. solution.

In an experiment performed last summer by the Botanical Department of Purdue University and not yet reported, it was found that oats immersed ten minutes in a solution containing one pound of formalin to fifty gallons of water, only eight-tenth per cent. of smutted plants were produced as against over twelve per cent. in the untreated ones.

A recent newspaper article[7] contains a brief notice of some experiments with formalin by Prof. Thomas of Wabash College, in which he found that oats treated half an hour in a one-half per cent. solution produced plants entirely free from smut as against about six per cent. in the untreated ones.

A few references have been found on the influence of formalin on the germination of the seed. Geuther[8] found that soaking the seed grain two hours in a 0.1 per cent. solution did not injure its germination. In a

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[4] Arthur, Ind. Agr. Exp. Sta. Bull., **65**: 23, 1897.

[5] Bolley, North Dakota Exp. Sta. Bull., **27**: 1897.

[6] Close, N. Y. Agr. Sta. Bull., **131**: 1897.

[7] Indianapolis News, Dec. 9, 1898.

[8] *l. c.*, 325-330.

one-fourth per cent. solution for the same length of time the seed was seriously affected.

Bolley[9] reports the effects of formalin on oats, barley and wheat. Seed of oats and barley immersed half an hour in a solution containing three parts formalin to one thousand parts of water gave normal germination nine days and nine months after treatment. Wheat immersed ten minutes in a two per cent. solution gave eighty-two per cent. germination.

Thomas[10] finds a one-half per cent. solution for oats and a treatment of about two hours produces no injury to the seed.

For wheat a one-fourth to one-half per cent. solution and an immersion of one-half hour is recommended. Rye was injured in a one-fourth per cent. solution when immersed but an hour.

SUMMARY.

A brief resumé of the data presented shows that the results obtained in the treatment of the spores are well within the bounds of successful practice.

The spores are much more easily injured either with hot water or formalin than is the grain.

It is apparent that the essential feature in the successful treatment of grain for smut is to bring each seed in contact with the solution used a sufficient length of time to enable it to reach the smut spores.

The advantage possessed by formalin over hot water in the treatment of seed grain lies in the greater ease of its application, doing away with the necessity of heating water and maintaining a reasonably uniform temperature during the period of treatment.

Lake Maxinkuckee. By J. T. Scovell.

During the summer of 1898 I traced out the sandbars in the southern portion of the lake. In doing this work I made about 100 soundings. In all we now have about 900 recorded soundings of the lake. The contour

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[9] *l. c.*, 130-132.

[10] Thomas, Proc. Ind. Acad. Sc., 148, 1897.

lines drawn from these soundings give a fairly correct idea of the topography of the lake bed.

Almost every sounding in five feet of water showed a bottom of hard sand or gravel, while almost every sounding in water ten feet deep indicated a bottom of fine mud, usually marl, from eight to twenty feet or more deep. In water more than thirty feet deep the mud is finer and darker, but I could get no idea of its depth. The hard bottom is much wider on the east side of the lake. It may be that the westerly winds give rise to an undercurrent which sweeps the finer material into the deeper water. But the same phenomenon occurs on the bars in the central portions of the lake where the wind would hardly cause currents. A few observations of the temperature of the water in the lake at different times of the day showed considerable variation and might cause currents. July 28th, at 7 a. m., the temperature in water about eighteen inches deep was 78 degrees Fahr., at 2 p. m. it was 84 degrees and at 8 p. m. 82 degrees; July 29th, at 7 a. m., 77 degrees, at 2 p. m., 87 degrees, at 8 p. m., 80 degrees; July 30th, at 7 a. m., it was 74 degrees, at 2 p. m., 82 degrees, at 8 p. m., 78 degrees; July 31st, at 7 a. m., 75 degrees, at 2 p. m., 84 degrees, at 8 p. m., 80 degrees; August 1st, at 7 a. m., 76 degrees, at 2 p. m., 82 degrees, at 8 p. m., 79 degrees; August 5th, at 7 a. m., 79 degrees, at 2 p. m., 82 degrees, at 8 p. m., 80 degrees; August 6th, at 7 a. m., 75 degrees, at 2 p. m., 80 degrees, at 8 p. m., 78 degrees. Whether changes of temperature ranging from five to ten degrees within twenty-four hours would cause currents strong enough to move fine sediment I cannot tell, but the idea is suggestive, and investigation along this line may show interesting results.

The lake shows considerable variations in level. Elevations taken by the Vandalia people at different dates in 1895, 1896, 1897 and 1898 show a variation from 733.3 to 735.17 feet, about 1.87 feet. In August, 1896, I saw a rise of six inches as the result of two days' rain.

I added over 100 species to my list of plants and trees found about the lake, extending it to about 290 species. We have a list of thirty-one species of fish found in the lake. Six species of bivalve mollusks and three or four species of univalves have been identified, and I think five species of turtles are found about the lake.

An Elevated Beach and Recent Coastal Plain Near Portland, Me. Notes of an Excursion with a Party Under Conduct of Prof. Wm. M. Davis, July, 1898. By Wm. A. McBeth.

[Abstract.]

Evidence pointing to the existence of such beach and recent plain in southern Maine as observed in the region of Portland are a belt of sand and gravel deposits closely following the three-hundred-foot contour line around an arm of the Casco Bay depression. The belt is quite continuous through the distance traced and apparently much further, and it slopes gently down toward the inclosed valley. Exposures along streams and in gravelpits, wells, etc., show depth and character of deposits. What are apparently sandpits modify the course of some of the streams crossing the deposits. Several drumlins stand on the upper border of the belt with bluff frontages upon it, which resemble the wave-cut drumlins in Boston Harbor. Undercut cliffs of rock also front upon it with heavy water-worn talus fragments at their base. The country falls off abruptly in places from the lower edge of the belt to the basin below. The floor of this depression is covered with a light gray marine clay, the drainage channels of which are narrow and steep-sided, showing recent origin.

The deposits of sand and gravel are thought to be a beach line elevated about 300 feet above the sea. Postglacial age is indicated by the wave-cut drumlins and undisturbed conditions of deposits. The much later age of the lower plain is indicated by the immature drainage lines and slight weathering. The order of movements evidently has been sinking of the region, deposition of clays in basin and formation of beach, elevation of from three hundred to four hundred feet, redrowning of the lower levels of the basin.

Wasted Energy. By Prof. J. L. Campbell.

A Vesuvian Cycle. By C. A. Waldo.

Ordinarily Vesuvius is in a state of mild activity. A single visit, however, does not show the periodical aspects of its manifestations. It was the fortune of the author of this note to visit Naples in the summers of 1890, 1891, 1894 and 1896, and on each of these occasions to make the

ascent of the volcano. The cinder cone has a diameter at its base of about one and one-half miles. It rests on a gently sloping hill, while its own angle of elevation is about 30°. This cone or new mountain is about 1,200 feet high and terminates in a comparatively level top, varying in diameter from 500 to 1,000 feet, and now about 4,200 feet above sea level.

In 1890 as we approached the summit we felt that it was shaken at intervals of about thirty seconds. Soon we noticed that the tremors were accompanied by a peculiar sighing and explosive sound. At the summit a cone of freshly-ejected material had been formed, forty or fifty feet high and 150 to 200 feet in diameter at the base. At each explosion a fountain of semi-fluid lava was projected to the height of 100 feet above the top of the crater. Most of this material rained back into the crater's mouth, into which we could not look, but much of it fell in fragments on the outside.

In 1891 the top of the cinder cone had undergone a complete change. The small cone surrounding the crater had entirely disappeared. In its place was a cavity 200 feet across and of unknown depth. The mouth of this cavity was filled with vapors and dark sulphurous gases which completely hid the boiling lava far below, and which, streaming into the air, gave to the mountain the appearance of smoking. But standing on the edge of the chasm a continual din deafened us and an occasional heavier explosion smote our ears.

In the Atrio del Cavallo, a deep valley to the north, between Monte Somma and the cinder cone, we could see the glow of fresh lava as it flowed from the mountain's side. During the previous year the hydrostatic pressure of the molten, liquid mass rising so high in the crater had forced an exit through the base of the cinder cone.

In 1894 lava no longer issued from the recent vent towards Monte Somma. During the intervening period, after the great pressure of 1890 had been removed, it had flowed more and more slowly until it began to clog the opening and finally sealed it completely. This vent, which in 1890 was in the direction of least resistance, must now be one of the strongest parts of the mountain. Thus one by one the weaknesses of the cinder cone are patched up until the conditions of strength are prepared which will compel the lava to flow out of the very top. Soon thereafter will follow a great eruption. Just as in 1891, there was in 1894, an open central crater, but by its continual "working" the mountain had filled up the bottom of the cavity, and the surface of the molten lava had risen

to a point about 150 feet below the edge of the crater. We now saw repeated the conditions of 1890 with this exception, that the building-up process had not reached the summit. From a secure position we could look down upon the molten lava and observe all the phenomena of the immature eruptions.

In 1896 the rising column of lava had once more forced a way for itself through the mountain's base. Again the crater was a dark, roaring cavern. But this time the vent was in the direction of the observatory to the west of the summit. The liquid lava had covered many acres, destroying a part of Cook's carriage road, and piling up a new hill a hundred feet high. A few inches beneath the surface this hill was still red hot, while from its summit two or three streams of live lava flowed sluggishly down its side.

In about five years Vesuvius had passed through one constructive cycle. These must succeed each other until the walls of the crater have sufficient resistance to allow the accumulation of an explosive energy. Then comes the short destructive period during which the retaining walls are seamed and shattered. In general the number of elementary cycles between great paroxysms will be in direct proportion to the work of restoration necessary, and this in turn will depend directly on the violence of the eruption immediately preceding.

X-Ray Transparency. By Arthur L. Foley.

[Abstract.]

Many experiments have been made to determine, and many tables given to show, the relative transparency of bodies to the X Rays. No two have been in agreement. The varied results cannot be attributed to uncertain methods or experimental errors, or, indeed, to the size, shape and general construction of the different tubes used. The degree of the vacuum seems to be the chief factor.

Two of the tubes used in this investigation were of the usual type—non-adjustable vacuum. At first they increased in efficiency, then decreased, and finally almost entirely lost their power of affecting a fluoroscope or photographic plate. At first the rays possessed little penetrating

power; that is, bodies were rather opaque. But as the vacuum became higher the penetrating power of the rays became greater, especially for dense bodies.

The third tube used was one of Queen's adjustable vacuum tubes. To obtain what is here called a low vacuum, the auxiliary spark gap was closed or short-circuited. To obtain a high vacuum the gap was made as long as possible. A photograph of the hand with a low vacuum showed flesh and bones almost equally opaque, while with a high vacuum the flesh was almost transparent. A photograph of a piece of glass, aluminum, steel, carbon, rubber and cork showed that the glass, aluminum and steel were more transparent to the high than to the low vacuum rays. The reverse was true of carbon and cork. No difference was noted with the rubber.

Soon after the X rays were discovered Edison announced that what are known as slow plates are the fastest for X rays. Here again the degree of the vacuum must be taken into consideration. For high-vacuum rays fast plates are most rapid.

The fluoroscopic action of the rays also changes with the vacuum, a rather low vacuum giving the best results.

Whatever be the nature of the X rays it is certain that they possess properties analagous in some respects to pitch and color.

The Trouble with Indiana Roads. By Daniel B. Luten.

A good road is defined as a road that is hard, smooth and serviceable at all seasons of the year.

The State of Indiana has 60,000 miles of wagon roads, of which about 8,000 miles have been improved by graveling or "piking," and now constitute our free gravel road system, maintained and repaired by the counties. The remaining 52,000 miles are nearly all dirt roads, and are maintained and repaired by the townships.

If we are to judge of Indiana roads by the above definition of good roads, we must admit that less than one per cent. of our 60,000 miles of roads are good roads. I do not mean that the remaining ninety-nine per cent. are always bad; but I do mean that for five or six months of every year they are bad, some of them extremely bad, and that at such

times they are passable for none but lightly-loaded and slow-moving vehicles. From the middle of May until the middle of July the roads are in excellent condition. A dirt road during these months is a splendid road; a gravel road is equally good. From the middle of July until the middle of October they are covered with dust, sometimes two or three inches in depth. Then come the fall rains, and the dusty roads absorb water like a sponge preparatory to December frosts. Then follow three months of good roads with frozen surface over the imprisoned water that is well content to wait, knowing that in March it will have ample opportunity to make trouble. And with the first of March the roads begin to thaw and break up, to be followed by two months of bad roads.

Of the 60,000 miles of roads in Indiana, 52,000 are unrideable for bicycles at nearly all seasons of the year, and the remaining 8,000 are rideable only during about four or five months in the early summer and late in the fall or winter.

There are seven good reasons why our roads are bad:

1. Because of lack of drainage, more especially of the surface water; failure to remove the surface water to the side ditches promptly permits it to saturate and soften even the hardest of road materials. The road surface should at all times be kept shaped like a roof to shed water, and to this end it is necessary always to keep ruts and chuckholes filled, and the surface smoothly and uniformly crowned. The first step in the maintaining of a road in good condition is to eradicate the ruts. And any plan or device that will prevent the forming of ruts will aid in providing good roads. Wide tires help to attain this end; a more clever device is the long doubletree, with the whiffletrees so attached that each horse must travel directly in the wheel track. The horses refuse to travel in the rut, and choosing the smoothest path, the wheels are drawn out of the rut, thus helping to roll it down instead of cutting it deeper.

2. Another reason why our roads are bad is because repairs are too long delayed. On road surfaces, more perhaps than upon any other kind of engineering structures, the repairs should be made promptly; an ounce of prevention is worth many pounds of cure.

3. A third reason for bad roads is because too much of the work on repairs is done at one time, on the principle, doubtless, that if a small dose is good, a large dose will be better.

Our gravel roads suffer most from this method of repairs. Late in the fall they are heaped ten or twelve inches deep with gravel and then al-

lowed to take care of themselves for another year, when they are given another dose, after which they are called "improved" roads!

The gravel is dropped in a heap in the middle of the road, usually with no attempt to spread it uniformly. And that is the fourth reason for our bad roads.

4. Too much material and too little labor. One-fifth as much new material would usually be sufficient, and the labor wasted in hauling the other four-fifths should be used in filling ruts and chuckholes instead.

5. Another reason is that the repairs are made at the wrong season of the year. Gravel roads are frequently repaired in the fall; then the heavy rains turn the new gravel into mush that freezes into a good road for the winter months, but breaks up into soft mud with the first thaw of spring.

The proper season for road repairs is all the time. They should be watched and repaired every day of the year.

6. Reason No. 6 is the use of improper road material. Broken stone applied to road surfaces should never be in sizes greater than one and one-half inches in diameter, and should contain at least twenty-five per cent. of stone screenings less than one-fourth inch in diameter. Gravel should be such that all of it will pass a one-inch sieve and twenty-five per cent. will pass a one-fourth inch sieve. Good road gravel contains no rocks larger than hulled walnuts; nor should there be more than five per cent. of clay present.

7. Another reason for bad roads is poor location; the policy of running roads on section lines is unwise, especially in hilly country. They ought to wind through the valleys and around the hills instead of over them. A proper location for a road is always a compromise between grades and distance. In hilly country the winding road will be an easier road for traffic, will be more picturesque and will frequently be shorter than the section-line road.

Having pointed out the reasons for bad roads, the next question is to find the remedy. I shall not propose better methods of construction; even macadam roads costing say three thousand dollars per mile would give us better service for but one or two years and then would become as bad as the rest if not properly maintained. There is only one kind of road that can be depended upon to remain in as good condition as when first constructed, and that is the corduroy road of olden times. And may Providence deliver us from that.

There is no such thing as a permanent road. They all require constant care and repairs. And the more perfect the road surface the greater will be the care and attention required to keep it smooth. It costs more to properly maintain a stone road than a gravel road. But a good stone road is a better road than a good gravel road.

Some theorists tell us that if we could have all the money that has been expended upon our bad roads we could pave them with gold. Our State has expended $70,000,000 in road repairs in the past forty years. We are told that if this sum had been expended in building permanent roads we would now have a complete system of good roads. They forget that good roads cost as much for maintenance as poorer roads; they forget that if we had expended $70,000,000 in building good roads in 1860, we would still have had to expend another $70,000,000 or more to keep them in good condition to the present time.

Or if, on the other hand, we had saved that $70,000,000 of repairs to now expend in building good roads we should for that forty years have had to get along with roads that would have been ten times worse than the ones we have had. For there is no denying that the expenditures that have been made upon our roads for repairs, although very wasteful and not a complete success, have been nevertheless of great benefit.

To go back to our search for a remedy, permit me to repeat the reasons for bad roads in Indiana:

1. Bad drainage.
2. Repairs delayed.
3. Too much repairing at one time.
4. Too much material, not sufficient labor.
5. Repairs at wrong season.
6. Improper material.
7. Poor location.

1. To secure proper drainage of surface water requires constant attention. All that is necessary is to keep the road crowned, but it must be watched and cared for at all times and especially in wet weather. There must be some one whose duty it is to keep the ruts and chuckholes filled and the ditches clear.

2. Repairs need not be delayed if some one is employed whose duty it is to attend to them promptly, provided there be a superintendent to see that he does his duty.

3. Repairs would not all be made at one time if a single attendant were employed for a long time instead of the present method of many men for a few days.

4. Too much material is used and too little labor, because material is usually cheap and labor is expensive, and because it is easier to tell a man how to haul a load of gravel than to tell him how to make tools for filling the ruts.

5. Place a man in charge of the road who has to attend to it constantly and he will soon learn that it is easier to keep it in good condition by scraping the ruts than by drawing on four times as much gravel as is essential.

6. Improper material is used because the men employed on repairs have neither the time nor the incentive to learn the qualities of road materials. This requires a certain amount of expert knowledge that can easily be gained by experience.

7. To remedy poor location requires only that a man should be able to see that it is easier to draw a load around a hill than over it. Teach the road attendant to ride a wheel and he will soon appreciate the difficulty of steep grades.

In short the reason our roads are bad is because nobody makes it a business to attend to them. And the remedy is a system of maintenance which shall make it somebody's business to keep them in good repair. Dirt roads should be in good condition for at least nine months of the year, and gravel roads ought to be good at all times.

By our present Indiana laws we have abundant provisions for superintendence, not perhaps of the most expert kind, but engineering skill is not necessary. What is more essential in a road superintendent is that he should have the power to discharge an attendant for lack of attention to duty, and that he should be able to tell when a road is not in good condition. As a matter of fact the average engineer is too apt to go to the other extreme and to attempt to construct permanent roads at great expense when our system of maintenance by no means warrants it, which would be as reckless as to invest in an expensive building and then fail to insure it against fire. Our roads should be divided into sections of not more than twenty miles in length; for each section a man and team should be employed, all of whose attention is to be devoted to the care of that road from the first day of March until the first day of December.

He should be employed by the day so that he may be liable to discharge at any time for neglect of duty. He should be selected by competitive bids for day labor of eight hours per day.

Man and team could be secured for nine months' service at the rate of $1.50 or less per day. The rate at present paid by our county commissioners for man and team is $2.50, because they are employed for but a few days at a time. And for this $2.50 a man is secured who takes no interest in the road and who piles on the material because it is easier to draw gravel than to spread it, and because it makes his job last longer.

To secure the adoption of such a system for our gravel roads requires only that county commissioners should be convinced that it is more desirable as well as more economical than present methods. They have full powers to act.

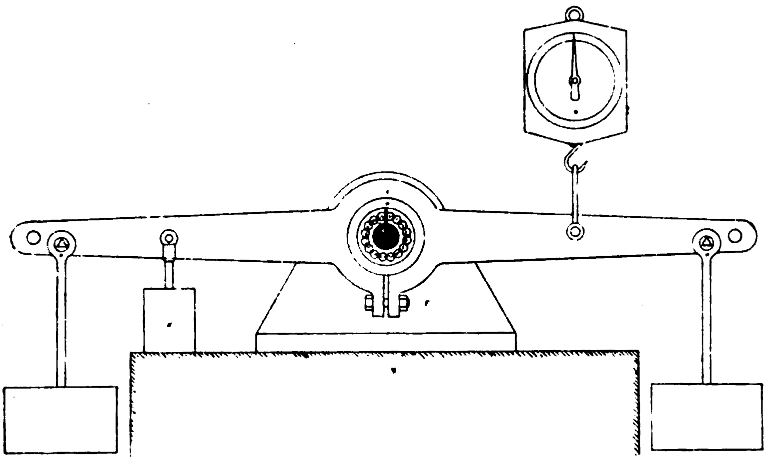
For our township roads it requires that all road taxes should be paid in money instead of in day labor as at present. The day-labor system produces the same kind of results that would be secured by a school system if the citizens assessed were permitted to work out their school taxes by taking turns in teaching the public school. When road taxes are paid in money, the division of township roads into sections, and the employment of attendants, will solve the road problem.

This method of maintenance by an attendant who devotes all of his time to the road, is in use in isolated cases in the United States, principally in New York State. In European countries it is acknowledged to be the only satisfactory method of maintenance, and it is the basis of the superb system of highways enjoyed by France and Germany.

Some Tests on Ball Bearings. By M. J. Golden.

These tests were made to determine the amount of power absorbed by ball bearings of the form used in supporting shafting and spindles, when the load is light. The bearing, in this set, was loaded with weights that varied from ten pounds (the weight of the parts) to three hundred pounds, by increments of forty pounds, except the last one; that was ten pounds. The apparatus used is shown in the sketch, where (A) is a spindle that is revolved by means of a belt from a counter-shaft. To this spindle is attached (B), the inner part of the ball race; the outer part

of the race being held in a cage (D) that is clamped inside the balanced arm (E). Near the extremities of the balanced lever are inserted knife edges that are on a line drawn through the center of the rotating spindle, and the weights used were suspended from these knife edges, as shown.



A dash-pot (H) was used to check the vibration of the lever; and the tendency of the lever to rotate, due to friction with the revolving spindle, was measured on a scale (G).

The method of operation was to first bring the lever nearly to balance, leaving a slight excess weight on the scale side, then on causing the spindle to rotate there was an additional pull on the scale arm, due to the friction of the moving parts. This additional pull, when reduced to the ball path on the part (c), could be used to find the coefficient of friction.

The following table will show the form of log kept:

BALL-BEARING FOR ONE INCH SHAFT.

(Oil Used.)

No.	Weight on Scale. Ounces.	Weight. Pounds.	Rev. Spindle.	Time. Seconds.	Heat.	Coefficient F.
7	¼	90	256	30	None.......	.0017
8	¼	90	442	30	None.......	.0017
9	⅜	90	757	30	None.......	.0026

BALL-BEARING FOR ONE INCH SHAFT—CONTINUED.

(Oil Used.)

No.	Weight on Scale. Ounces.	Weight. Pounds.	Rev. Spindle.	Time. Seconds.	Heat.	Coefficient F.
10	⅜	130	256	30	None.......	.0018
11	⅜	130	431	30	None.......	.0018
12	⅜	130	758	30	None.......	.0018

Three sets were made for each load, and, with the weights used, the coefficient of friction varied from .0017 to .0022, as averages for the three sets. Of course, the width of this range may be due to inaccuracy in reading from the scale, as the variation in pull on the scale arm caused a rapid vibration of the scale index.

The bearings used were those supplied on the market for carrying shafts, and the principal cause of the jar in the apparatus during the test was due to slight inaccuracies in grinding the races.

In another set of tests, where the load was increased to seven hundred pounds, it was found that somewhere between the six hundred and the seven hundred pounds load the balls and races had become pitted, small pieces of the hardened steel being torn from the surfaces. These pieces were found in the race-way or in the oil that was used. It was found, further, that the tendency to heat was much reduced when oil was used and that the whole movement was smoother and steadier.

Further Studies in the Propagation of Sound. By A. Wilmer Duff.

[Abstract.]

In a previous paper the writer gave a theoretical discussion of the propagation of sound in spherical waves, allowing for the effect of the viscosity of the air and the conduction and radiation of heat from the condensations and to the rarefactions. It resulted from this investiga-

tion that at short distances from the source the intensity of the sound varies as

$$\frac{1}{r^2}\left(1+\frac{a^2}{n^2 r^2}\right),$$

while at great distances from the source the intensity varies as

$$\frac{e^{-2mr}}{r^2}.$$

In these formulæ r stands for the distance from the source, a for the velocity of sound, and n for the number of vibrations per second, while m is a constant that depends on viscosity conduction and radiation.

In the previous paper the author described experiments made to find the value of m. The method was confessedly not altogether satisfactory. Later another method was devised and applied during the summer of 1898. As before, the work was performed in the open air at a very quiet part of the River St. John, New Brunswick, Canada. The season was very unfavorable, and only the few results hereafter described were obtained.

The greatest difficulty in such work is in finding a variable standard of intensity of the same pitch and quality as the sound studied. In the present case this was overcome by using the sound conveyed through a telephone as the standard, the transmitter being placed near the source of sound and the receiver held at such a distance from the ear that the sound heard directly and that heard through the telephone were of equal intensity. Only one ear was used, the other being filled with wool and closely covered by a heavy pad. This use of a telephone receiver at different distances from the ear as a standard implied a knowledge of the law of intensity of the sound at different distances from the receiver. This point, the law of intensity at short distances, was first tested by using the receiver in two states of intrinsic sensitiveness—first, shunted; second, not shunted. Now, if a series of sounds of different intensities (e. g., the sound of the same whistle differently deadened by coverings) be compared with these two standards, the ratio of the two intensities thus estimated for each sound should be the same for all the sounds, and if calculation according to the theoretical law above stated for short distances should show such a constancy of ratio, it would afford strong evidence that the theoretical law is correct. The tables of results obtained

verified the law of intensity at short distances and showed that the commonly accepted law of inverse squares at short distances is quite inapplicable.

Having thus verified the theoretical law for short distances, the use of the telephone receiver as a standard for estimating the intensity at great distances from the source becomes possible.

Tables of results summarizing the observations obtained at great distances showed that the values of m required to reconcile the observed variations of intensity at each increase of distance with the theoretical law at great distances increased uniformly; and hence it is evident that the theoretical law can not be quite correct. In fact, there must be another cause of decay of intensity not taken account of in the theoretical discussion; and this other cause, whatever it is, produces results not in accord with an exponential law of variation. What this other cause is, the author does not undertake to say.

THE INTENSITY OF TELEPHONIC SOUNDS. BY A. WILMER DUFF.

[Abstract.]

If a sound of constant intensity act on a telephone transmitter, the intensity of the sound given off from the receiver will depend upon the total resistance, inductive and non-inductive, of the circuit. If the circuit include a resistance box and the total resistance be varied in a known way, the relative changes of current affecting the receiver can be calculated. If, now, the receiver be held at varying distances from the ear, so that the sound emitted by it seems to the ear as loud as the sound heard directly from the distant source that acts upon the transmitter, then the variations in intensity of the sound given off by the receiver can also be estimated. (See preceding article.)

By this method it was found that the intensity of sound emitted by the receiver varied roughly as the three-halves power of the current traversing the circuit.

The Distance to Which Small Disturbances Agitate a Liquid.

By A. Wilmer Duff.

[Abstract.]

In the course of an unfinished piece of work on a new method for determining the viscosity of water, the following somewhat curious result was obtained:

If a sphere of one centimeter radius hang from an arm of a balance by a long fine wire, and be immersed in a vessel of water, it may be caused to perform vertical vibrations of any desired extent and rapidity by suitably weighting the pans of the balance. The nearness of the sides of the vessel will be found to greatly affect the rate at which the vibrations die down. Even when the sides of the vessel are very distant, they have an appreciable effect. When the vessel is a large-sized carboy, the effect of the sides is still quite appreciable. That is to say, if a sphere of one centimeter radius perform one vibration for every fifteen seconds through a range of one centimeter in a mass of water, the effect on the water at a distance of a foot from the sphere is quite appreciable and measurable, the water being agitated to that distance instead of merely flowing round the slowly moving sphere to fill up the space it vacates.

It may be added that the method referred to for measuring the viscosity of water is not intended as a practical method for finding the viscosity of different liquids, but merely as a means of contributing to the settlement of the dispute regarding the discordant values of the viscosity of water obtained by the several other methods that have been employed.

The Evaporation of Water Covered by a Film of Oil.

By A. Wilmer Duff.

[Abstract.]

A vessel of water covered by a film of paraffin oil 4 mm. thick and placed in a box artificially kept dry, lost 4 gms. of water in two months, while in another case in which the film of oil was only 1 mm. thick the loss in two months was 11 gms. After considerable difficulty it was proven that this loss was not at all due to a passage of the water through

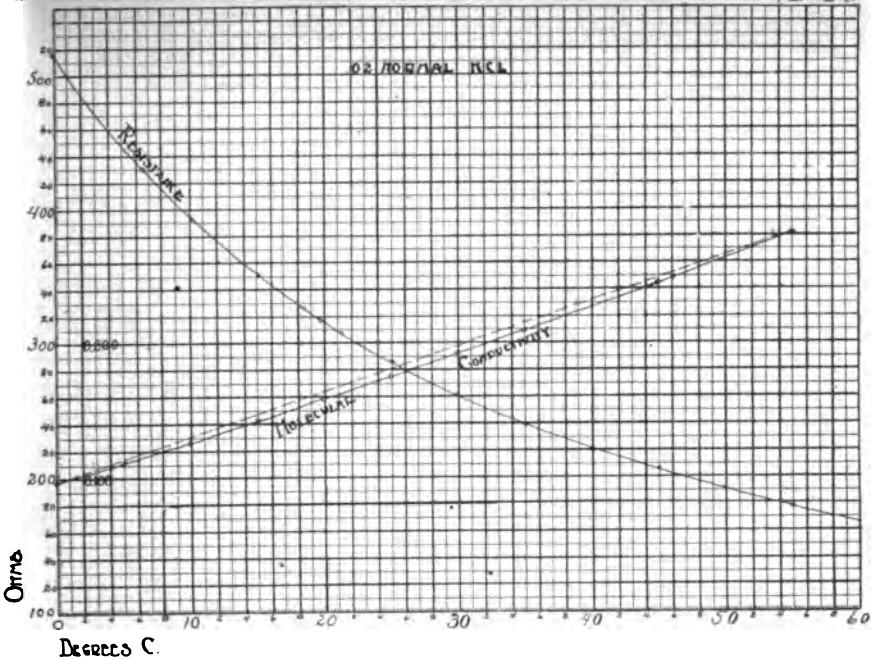
the oil film, but to the water creeping out between the oil and the glass. This may be tested by placing two similar glass vessels on the pans of a sensitive balance, pouring some water in one and covering it with a layer of oil, and pouring in the other oil only to the same depth. After counterbalancing and closing the balance case very tightly to prevent air currents, the arms may be kept counterbalanced by suitable riders, and it will be found that the evaporation of the water takes place with sufficient rapidity to be measured in a short time. But if the water be contained in a watch-glass placed in the bottom of the glass vessel and entirely covered and surrounded by oil, no evaporation will be discovered.

To indicate the rate at which water can thus creep between oil and glass, it may be stated that when the glass vessel is 9 cm. in diameter and the layer of oil as much as ½ cm. thick, the evaporation takes place at the rate of nearly a milligram per hour.

A Note on Temperature Coefficient of Electrical Conductivity of Electrolytes. By Arthur Kendrick.

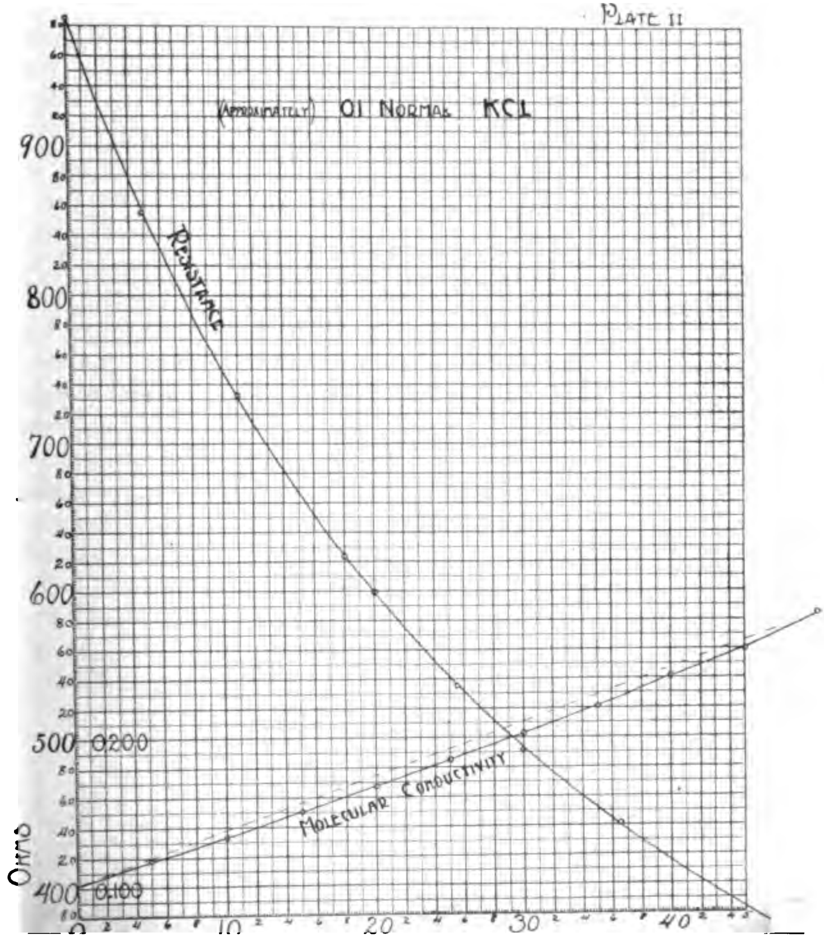
[Abstract.]

This paper was a preliminary note of work begun to determine the temperature coefficient of conductivity of various electrolytes of varying concentrations. The two plates give the curve of resistance and molecular conductivity in the case of a $\frac{2}{100}$ normal KCl aqueous solution and an approximately $\frac{1}{100}$ normal KCl aqueous solution, between 0° C and about 50°. The figures 0.100 and 0.200 mark the ordinates of the molecular conductivity curves. The resistances in each case are the actual, corrected resistances for the cell used; and the molecular conductivity is the resistance, taken from the curve divided by $\frac{2}{100}$ and $\frac{1}{100}$ respectively, the concentration values. The broken straight lines are drawn to make noticeable the curvature.



.02 NORMAL KCL
RESISTANCE
MOLECULAR CONDUCTIVITY
OHMS
DEGREES C.

PLATE II



(APPROXIMATELY) .01 NORMAL KCL
RESISTANCE
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OHMS

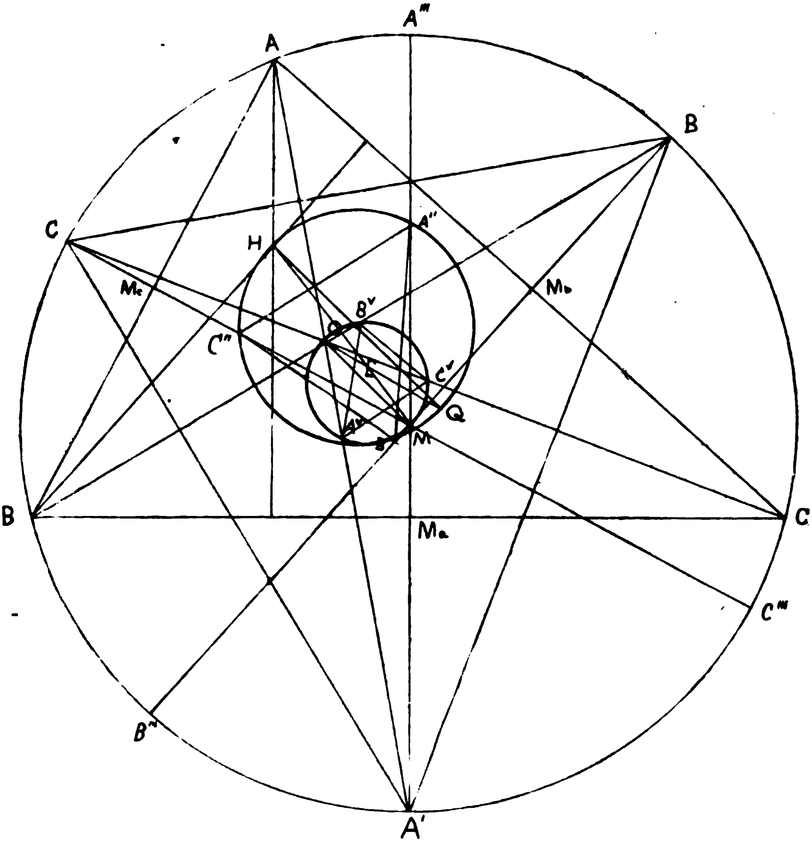
A Common Text-Book Error in the Theory of Envelopes.

By A. S. Hathaway.

The cause of this communication is the recent appearance of several text-books on the calculus that embody an error in the theory of envelopes that dates at least as far back as Todhunter's calculus, and is now reproduced in all text-books under the impression, apparently, that it has acquired the sanction of authority, although Cayley pointed out the error nearly forty years ago, while the subject matter is presented in all text-books on Differential Equations in its correct form. The error consists in defining the envelope of a moving curve as the locus of its self-intersections, and then proving that the envelope touches the moving curve in every position—i. e., proving as true that which is often false—for the locus of self-intersections of a moving curve may cut the curve at any angle, as at right angles, wherever the two meet. A simple example is the curve $(y-m)^2=(x-3)^3$, whose locus of self-intersections, as m varies, is the straight line $x=3$, which cuts every curve of the given system at right angles. The fact is, that the envelope should be *defined* as the curve that touches every curve of a given system. It can then be shown it is *a* locus of self-intersections of the curves of the system, provided such self-intersections are not the singular points of the given system. The locus of such singular points is always a locus of self-intersections, but it is not in general an envelope of the system, and may cut every curve of the system at any constant or varying angle. The text-book blunder referred to is of the same logical character as would be the attempt to prove that a quadruped is a horse. To be sure, a horse is a quadruped, but not every quadruped is a horse. Thus a curve that touches every curve of a given system is a locus of self-intersections of the system, but not every locus of self-intersections of the system will touch every curve of the system. The error in the proof arises out of the assumption that if two points of a curve approach coincidence, the limiting position of the chord joining the two points is a tangent line at the point of coincidence. This is all right if the point of coincidence is not a singular point of the curve. But at a singular point, as a sharp point like the bottom of a letter V, the limiting position of two points that approach the point on opposite sides is absolutely indeterminate, and is not necessarily a tangent line at that point.

A New Triangle and Some of Its Properties. By Robert Judson Aley.

Explanation of Figure. — ABC is any triangle, of which M is the circumcenter, O the incenter, H the orthocenter, and Q Nagel's Point. $A'A'''$, $B'B'''$ and $C'C'''$ are diameters perpendicular to the sides BC, CA, AB, respectively.



I. If A^{v}, B^{v}, C^{v} are the middle points of AA', BB', CC', respectively, then OM is the diameter of the circumcircle of $A^{v}B^{v}C^{v}$.

Since A^{v} is the middle point of AA',

MA^{v} is parallel to AA'''.

But AA''' is perpendicular to AA',

$\therefore$ MA^{v} is perpendicular to AA'.

Hence $MA^{v}O$ is a right angle.

Similarly $MB^{v}O$, and $MC^{v}O$ are right angles.

$\therefore$ a circle upon OM as diameter will pass through A^{v}, B^{v}, C^{v}.

II. The triangle $A^{v}B^{v}C^{v}$ is similar to Nagel's triangle $A''B''C''$.

$\angle B^{v}C^{v}A^{v}$ is the supplement $\angle B^{v}OA^{v}$.

$$\angle B^{v}OA^{v} = \angle AOB.$$
$$= \pi - (\tfrac{1}{2}A + \tfrac{1}{2}B).$$
$$= A + B + C - \tfrac{1}{2}(A + B).$$
$$= C + \tfrac{1}{2}(A + B).$$
$$\pi - \angle B^{v}OA^{v} = \pi - [C + \tfrac{1}{2}(A + B)].$$
$$= A + B + C - [C + \tfrac{1}{2}(A + B)].$$
$$= \tfrac{1}{2}(A + B).$$

$\therefore B^{v}C^{v}A^{v} = \tfrac{1}{2}(A + B)$.

MA^{v} is perpendicular to AA'.

MC^{v} is perpendicular to CC'.

$\angle (MA^{v}, MC^{v}) = \angle (AA', CC')$.

i. e., $\angle A^{v}MC^{v} = A'OC$.
$$= \tfrac{1}{2}(A + C).$$

But $\angle A^{v}MC^{v} = A^{v}B^{v}C^{v}$.

$\therefore \angle A^{v}B^{v}C^{v} = \tfrac{1}{2}(A + C.)$

Similarly $\angle B^{v}A^{v}C^{v} = \tfrac{1}{2}(B + C)$.

The angles of the triangle $A''B''C''$ (Nagel's triangle) are $\tfrac{1}{2}(B + C)$, $\tfrac{1}{2}(A + C)$, $\tfrac{1}{2}(A + B)$, respectively. (Schwatt's Geometric Treatment of Curves, page 39.)

$\therefore$ $A^{v}B^{v}C^{v}$ is similar to $A''B''C''$. It is also similar to $A'B'C'$, for $A'B'C'$ and $A''B''C''$ are similar.

III. O is the centre of perspective of $A^{v}B^{v}C^{v}$ and $A'B'C'$.

IV. E, the centroid of ABC, is the internal center of similitude of the circumscribing circles of $A''B''C''$ and $A^{v}B^{v}C^{v}$.

OM is parallel to HQ.

It is known that H, E, M, are collinear, as are also O, E, Q.

$\therefore$ HM and OQ intersect at E.

$\therefore$ E is the internal center of similitude.

V. E is also the center of perspective of $A^{v}B^{v}C^{v}$ and $A''B''C''$.

For, consider the triangle $AA''A'$.

$A''A^{v}$ is a median and so is AM_{a}.

$\therefore$ $A''A^{v}$ passes through E.

Now consider the triangle $BB''B'$.

$B''B^v$ is a median and so is BM_b.

$\therefore$ $B''B^v$ passes through E.

In the same way we can show that $C''C^v$ also passes through E.

$\therefore$ E is the center of perspective of $A''B''C''$ and $A^vB^vC^v$.

VI. All the lines in $A^vB^vC^v$ are just one-half the corresponding lines in $A''B''C''$.

This is an immediate consequence of the fact $OM = \frac{1}{2}HQ$. (Schwatt, Geomet. Curves, page 40.)

VII. The sides of the triangle $A^vB^vC^v$ are oppositely parallel to the corresponding sides of $A''B''C''$, *i. e.*, A^vB^v is parallel to $B''A''$, etc.

OM is parallel to HQ.

HA'' is perpendicular to AA'.

MA^v is perpendicular to AA'.

$\therefore \angle A''HQ = \angle OMA^v$.

In the same way

$\angle B''HQ = \angle OMB^v$.

$\angle C''HQ = \angle OMC^v$.

This shows that the points A^v, B^v, C^v are located with respect to O, just as A'', B'', C'' are located with respect to Q.

$\angle (OM, B^vA^v)$ is measured by $\frac{1}{2}$ (arc OB^v + arc A^vC^v + arc C^vM).

$\angle (HQ, A''B'')$ is measured by $\frac{1}{2}$ (arc $B''Q$ + arc $A''C''$ + arc $C''H$).

But arc OB^v measures the same angle in the circle on OM as diameter, that the arc $B''Q$ measures in the circle on HQ as diameter.

The same is also true of the arcs A^vC^v and $A''C''$, and C^vM and $C''H$.

$\therefore \angle (OM, B^vA^v) = \angle (HQ, A''B'')$.

But since OM is parallel to HQ, we have at once $A''B''$ parallel to B^vA^v.

In the same way we may prove that $B''C''$ is parallel to C^vB^v and $C''A''$ parallel to A^vC^v.

$\therefore$ the sides of $A^vB^vC^v$ are oppositely parallel to the corresponding sides of $A''B''C''$.

VIII. The triangle $A^vB^vC^v$ is Nagel's triangle for the triangle $M_aM_bM_c$.

It is known (Schwatt, page 41) that O is Nagel's point in the triangle $M_aM_bM_c$, and that M is the orthocenter. The circle on OM as diameter is Nagel's circle for the triangle $M_aM_bM_c$. We know that the sides of $M_aM_bM_c$ are oppositely parallel to the sides of ABC, and we have proven that $A^vB^vC^v$, inscribed in the Nagel's circle of $M_aM_bM_c$, has its sides oppositely parallel to the sides of Nagel's triangle for ABC.

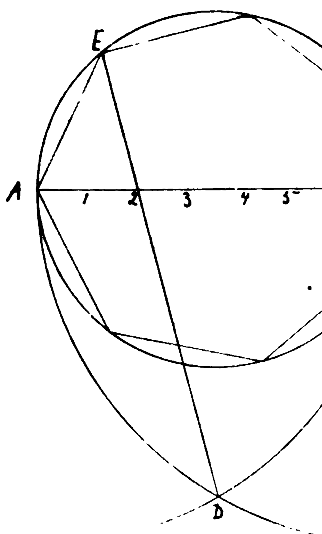
$\therefore$ $A^vB^vC^v$ is Nagel's triangle for $M_aM_bM_c$.

Note on Angel's Method of Inscribing Regular Polygons.

By Robert Judson Aley.

On page 47, "Practical Plane and Solid Geometry," by Henry Angel, the following method of inscribing a regular polygon in a circle is given:

"Let ACB be the given circle, and let the required figure be a heptagon. Draw the diameter AB, and divide it into seven equal parts. (The number of parts is regulated by the required number of sides.) With A and B as centers—radius AB—describe two arcs intersecting in D. From D draw the line D 2, passing through the second division of the diameter, and produce it, to meet the circle in E. The distance, AE, will divide the circle into seven equal parts; and if the points of division be joined, a heptagon will be inscribed in the circle."



The method has the merit of seeming to succeed. When applied to circles of short radii, no noticeable error is found in the drawing. I have not attempted to give a geometric demonstration of the error which arises in this and all similar rule of thumb methods of inscribing regular polygons. Let the diameter AB, for convenience, be fourteen units in length; then, by obvious trigonometric processes, we find AE to be 6.09212 units in length, while in a true heptagon the side would be 6.07436 units long.

Take a circle whose diameter is thirty-six units; Angel's method makes the side of a 36-gon equal to 3.33982 units, while the true length is 3.13776 units. The larger number of sides makes the error of the method more apparent.

Concurrent Sets of Three Lines Connected with the Triangle.

By Robert Judson Aley.

To the student of the pure geometry of the triangle, few subjects are more interesting than the concurrency of lines. The following collection of concurrent sets of three lines has been made in the hope that it may prove of value to geometric students. No claim is made to completeness. The list is as complete as the author could make it with the material to which he had access. Many of the notes, and a large number of the propositions have been taken from the published papers of Dr. J. S. Mackay, of Edinburgh, perhaps the foremost student of the geometry of the triangle. No classification of the propositions seems possible and so none has been attempted.

1. The median lines of a triangle are concurrent. The point of concurrency, usually denoted by G, is called the *median point* or centroid.

2. The in-symmedian lines of a triangle are concurrent. The point of concurrency is called the symmedian point or Grebe's point, and is generally denoted by K. (For a history of this point, see J. S. Mackay, in Proceedings of Edinburgh Mathematical Society, Vol. XI.)

3. The altitudes of a triangle are concurrent. The point of concurrency, usually denoted by H, is called the ortho centre. (This proposition occurs in Archimedes's Lemmas and in Pappus's Mathematical Collection.)

4. The internal angle bisectors of a triangle are concurrent. The point of concurrency is the center of the inscribed circle and is usually denoted by I. (Euclid IV, 4.)

5. The internal bisector of any angle of a triangle and the external bisectors of the other two angles of the triangle are concurrent. The points of concurrency, denoted by I_1, I_2, I_3 are the centers of the three escribed circles.

6. The perpendiculars to the sides of a triangle at the midpoints of the sides concur at the center of the circumscribed circle. This point of concurrence is usually denoted by O. (Euclid.)

7. Lines drawn from the vertices to the points of contact of the in-circle with the opposite sides are concurrent. (The point of concurrency, Γ, is called the Gergonne Point. It was named by J. Neuberg after J. D. Gergonne.)

8. Lines drawn from the vertices to the points of contact of the escribed circles with the opposite sides concur at Q, Nagel's Point. (For a number of interesting properties of this point, see Schwatt's "Geometric Treatment of Curves.")

9. Lines drawn from the vertices making equal angles with the sides AB, BC, CA, respectively, concur at Ω and Ω', the two Brocard points of the triangle.

10. If A_1, B_1, C_1, is Brocard's first triangle, then AA_1, BB_1, CC_1, concur at D, the point isotomic conjugate to K.

11. If L, M, N, be the midpoints of the sides of the triangle ABC, and L', M', N' the midpoints of the sides of the triangle $A_1B_1C_1$, then LL', MM' and NN' concur at S.

12. AL', BM', and CN' concur at S'. S and S' are isogonal conjugate points. (Schwatt's "Geometric Treatment of Curves," p. 5.)

13. Perpendiculars from A, B, C upon B_1C_1, C_1A_1, A_1B_1, respectively, concur at N, a point on the circumcircle of the triangle ABC, known as *Tarry's Point.*

14. Lines through A, B, C, parallel to B_1C_1, C_1A_1, A_1B_1, respectively, concur at a point on the circumcircle of the triangle ABC known as *Steiner's Point.*

15. Parallels to AB and CA through C and B, respectively, concur with the median through A. There are evidently three such points of concurrency. These points are sometimes called the *external median points.*

16. If three lines through the vertices are concurrent, their isogonal conjugates with respect to the angles of the triangle are also concurrent. (Steiner's Gesammelte Werke I., 193, 1881.) If the ratios of the distances of the first point from the sides are $l : m : n$, those of the second point are

$$\frac{1}{l} : \frac{1}{m} : \frac{1}{n}.$$

17. Perpendiculars to the sides of the triangle ABC from the midpoints of the sides of the orthic triangle of ABC are concurrent. (Edouard Lucas in Nouvelle Correspondance Mathématique II, 95, 218, 1876.)

18. The ex-symmedians from any two vertices and the in-symmedian from the third vertex are concurrent. There are evidently three such points of concurrency. They are sometimes called the *external symmedian points.*

19. If three lines drawn from the vertices of a triangle to intersect the opposite sides are concurrent, the lines isotomic conjugate to them are also concurrent. If the ratios of the distances of the first point of concurrency from the sides are $l \cdot m : n$, the ratios of the second point are

$$\frac{1}{a^2 l} : \frac{1}{b^2 m} : \frac{1}{c^2 n}.$$

20. If the three perpendiculars from the vertices of one triangle upon the sides of another triangle are concurrent, then the three perpendiculars from the vertices of the latter upon the sides of the former are also concurrent. (Steiner, Gesammelte Werke I., 157, 1881.) (Lemoine calls such triangles *orthologous* and the points of concurrency *centers of orthology*.

21. Brocard's Triangle and ABC are orthologous. Perpendiculars from A_1, B_1, C_1, upon BC, CA, AB, respectively, are concurrent. (See No. 13.)

22. If three points be taken on the sides of a triangle such that the sums of the squares of the alternate segments taken cyclically are equal, the perpendiculars to the sides of the triangle at these points are concurrent. (T. G. de Oppel, "Analysis Triangulorum," p. 32, 1746.)

23. If on the sides of a triangle ABC, equilateral triangles LBC, MCA, NAB be described externally, AL, BM, CN are equal and concurrent.

24. If on the sides of a triangle ABC, equilateral triangles $L'BC$, $M'CA$, $N'AB$ be described internally, AL', BM' CN' are equal and concurrent. (Dr. J. S. Mackay gives 24 in Vol. XV of Proceedings of Edinburgh Mathematical Society and attributes 23 to T. S. Davies in Gentleman's Diary for 1830, p. 36.)

25. If $A''B''C''$ be Nagel's triangle, then perpendiculars from A, B, and C upon $B''C''$, $C''A''$, $A''B''$, respectively, are concurrent.

26. Perpendiculars from A'', B'', C'' upon BC, CA, AB, respectively, are concurrent.

27. If A', B', C' be the midpoints of the arcs subtended by BC, CA, AB, respectively, then perpendiculars from A', B', C' upon $B''C''$, $C''A''$, $A''B''$, respectively, are concurrent.

28. Perpendiculars from A'', B'', C'' upon $B'C'$, $C'A'$, $A'B'$, respectively, are concurrent.

29. If distances equal to $2r$ (diameter of the inscribed circle) be laid off from the vertices on each of the altitudes, three points A^{iv}, B^{iv}, C^{iv} are obtained. Perpendiculars from A, B, C upon $B^{iv}C^{iv}$, $C^{iv}A^{iv}$, $A^{iv}B^{iv}$, respectively, are concurrent.

30. Perpendiculars from A^{iv}, B^{iv}, C^{iv} upon BC, CA, AB, respectively, are concurrent. (Nos. 25, 27 and 29 are given in Schwatt's "Geometric Treatment of Curves," pages 40, 43 and 44. Nos. 26, 28 and 30 are direct consequences of the orthologous relation of the triangles. See No. 20.)

31. The perpendiculars from the middle points of the sides of Brocard's first triangle upon the corresponding sides of the triangle ABC are concurrent.

32. The lines joining the middle points of the sides of a triangle with those of the segments towards the angles of the corresponding altitudes meet in a point and bisect each other.

33. The straight lines which join the midpoint of each side of a triangle to the midpoint of the corresponding altitude concur at the *symmedian point.* (Dr. F. Wetzig in Schlömlich's Zeitschrift, XII, 289.)

34. If two sides of a triangle are divided proportionally the straight lines drawn from the points of section to the opposite vertices, will intersect on the median from the third vertex.

35. Every two perpendiculars to the sides of a triangle at points of contact of escribed circles external to the same vertex are concurrent with the perpendicular to the opposite side at the point of contact of the inscribed circle. There will be three such points of concurrency.

36. If the three sides of a triangle be reflected with respect to any line, the three lines through the vertices parallel to the reflexions of the opposite sides are concurrent.

37. The vertices of ABC are joined to a point O, and a triangle $A'B'C'$ is constructed having its sides parallel to AO, BO, CO respectively. Lines through A', B', C' parallel to the corresponding sides of the triangle ABC are concurrent.

38. If XYZ be any transversal of the triangle ABC, and if AX, BY, CZ form the triangle PQR, then AP, BQ, and CR are concurrent.

39. If D, E, F be the feet of the altitudes, then the lines connecting A, B, C to the middle points of EF, FD, DE, respectively, concur at the symmedian point.

40. The perpendiculars from A, B, C upon EF, FD, DE are concurrent.

41. Through the vertices of the triangle ABC lines parallel to the opposite sides are drawn, meeting the circumcircle in A', B', C'. $B'C'$, $C'A'$, $A'B'$ meet BC, CA, AB in P, Q, R, respectively. AP, BQ, CR are concurrent.

42. With the same notation as 41, $A'P$, $B'Q$, $C'R$ are concurrent. (41 and 42 occur in St. John's College Questions, 1890.)

43. Three circles are drawn each touching two sides of the triangle ABC and the circumcircle internally. The points of contact with the circumcircle are L, M, N, respectively. AL, BM, CN are concurrent.

44. If in 43 the circles touch the circumcircle externally in L', M', N', then $L'A$, $M'B$, $N'C$ are concurrent. (43 and 44 are given by Professor de Longchamps, Ed. Times, July, 1890.)

45. If a circle touch the sides of the triangle ABC in X, Y, Z, then the lines joining the middle points of BC, CA, AB to the middle points of AX, BY, CZ, respectively, are concurrent.

46. If a circle cut the sides of the triangle ABC in X, X'; Y, Y'; Z, Z'; if AX, BY, CZ are concurrent, so also are AX', BY', CZ'.

47. If X, Y, Z be three points on the sides of the triangle ABC such that the pencil $D(AC, EF)$ is harmonic, then AD, BE, CF are concurrent.

48. If tangents to the circumcircle at the vertices of the triangle ABC, meet in L, M, N, then AL, BM and CN are concurrent.

49. If on the sides of the triangle ABC, similar isosceles triangles LBC, MCA, NAB be described, AL, BM, CN are concurrent.

50. If the ex-circles touch the sides to which they correspond in D_1, E_2, F_3, the perpendiculars to the sides through these points are concurrent.

51. If D, E, F are the points of contact of the incircle with the sides of the triangle ABC and if DI, EI, FI meet EF, FD, DE in L, M, N, respectively, then AL, BM, CN concur.

52. If DD', EE', FF' are diameters of the incircle through D, E, F, the points of contact with the sides of the triangle ABC, then AD', BE', CF' concur.

53. If P, Q, R be collinear points in the sides BC, CA, AB of the triangle ABC, and if P', Q' R' be their harmonic conjugates with respect to those sides then AP', BQ', CR' are concurrent.

54. If squares $APQB$, $BUVC$, $CXYA$ be described upon the sides of the triangle ABC (all externally or all internally) and if QP meet XY in α, PQ meet VU in β, UV meet YX in γ, then αA, βB, γC concur in K the symmedian point. (Halsted, "El. Synthetic Geometry," p. 150.)

55. $A'B'C'$ is the pedal triangle of Ω, and $A''B''C''$ is the pedal triangle of Ω'. $B''C'$, $C''A'$, $A''B'$ form the triangle XYZ, whose sides are parallel to the sides of ABC. PQR is *the* pedal triangle of ABC. PX, QY, RZ concur at the circumcenter of XYZ.

56. The Simson lines of the median triangle LMN of the triangle ABC, with respect to the vertices P, Q, R of the pedal triangle, concur at the center of Taylor's circle.

57. The Simson lines of the pedal triangle PQR of the triangle ABC, with respect to the vertices L, M, N of the median triangle concur at the center of Taylor's circle.

58. If BW, CV be perpendicular to BC; CU, AW perpendicular to CA; AV, BU perpendicular to AB; then AU, BV, CW concur at the circumcenter of ABC. (C. F. A. Jacobi, "De Triangulorum Rectilineorum Proprietatibus," p. 56.)

59. If triangles $A_1B_1C_1$ and $A_2B_2C_2$ are circumscribed about the triangle ABC in such a manner that their sides are perpendicular to those of ABC, then A_1A_2, B_1B_2. C_1C_2 concur at the circumcenter of ABC. (Probably known

by Jacobi, but not explicitly stated by him. Lemoine stated it in 1873 to the Association Française pour l'Avancement des Sciences.)

60. When three lines through the vertices of a triangle are concurrent, the six bisectors of the three angles they determine intersect with the corresponding sides of the triangle at six points, every three of which on different sides connect concurrently with the opposite vertices if an odd number of them is internal.

61. When three points on the sides of a triangle are collinear, the six bisections of the three segments they determine connect with the corresponding vertices of the triangle by six lines, every three of which through different vertices are concurrent if an odd number of them is internal.

62. When three points on the sides of a triangle are collinear, their three lines of connection with the opposite vertices determine an exscribed triangle whose vertices connect concurrently with those of the original to which they correspond.

63. H_1, H_2, H_3 are points of intersection of AI, BI, CI, respectively, with the inscribed circle. The perpendiculars from H_1, H_2, H_3 upon BC, CA, AB, respectively, are concurrent.

64. The twelve radii from the incenter and the excenters of a triangle, perpendicular to the sides of the triangle, meet by threes in four points which are the circumcenters of the triangles $II_2 I_3$, $II_3 I_2$, $I_3 I I_1$, $I_2 I_1 I$. (I, I_1, I_2, I_3 are the incenter and excenters. See note, p. 99, Vol. I, Proceedings Edinburgh Math. Soc., Dr. Mackay).

65. D, E, F are points of contact of I-circle with the sides of the triangle ABC, D_1, E_1, F_1 points of contact of I_1-circle with sides, D_2, E_2, F_2, of I_2-circle, D_3, E_3, F_3 of I_3-circle.

AD_1, BE_1, CF_1 concur at Γ_1
AD_2, BE_2, CF_2 concur at Γ_2
AD_3, BE_3, CF_3 concur at Γ_3

The points Γ_1, Γ_2, Γ_3 are called the associated Gergonne points. See No. 7.

66. AD_1, BE_3, CF_2 concur at Q_1
AD_3, BE_1, CF_1 concur at Q_2
AD_2, BE_1, CF concur at Q_3

Q_1, Q_2, Q_3, together with Q given in No. 8, are called the Nagel points.

67. AQ, BQ_3, CQ_2 concur at Γ_1.
AQ_3, BQ, CQ_1 concur at Γ_2.
AQ_2, BQ_1, CQ concur at Γ_3.

68. $A\Gamma$, $B\Gamma_3$, $C\Gamma_2$ concur at Q_1.
$A\Gamma_3$, $B\Gamma$, $C\Gamma_1$ concur at Q_2.
$A\Gamma_2$, $B\Gamma_1$, $C\Gamma$ concur at Q_3.

69. AB, DE, D_2E_1 concur at x.
BC, EF, E_3F_2 concur at y.
CA, FD, F_1D_3 concur at z.
x, y, z lie on a line n, say.

70. AB, D_1E_2, D_3E_3 concur at x_1.
BC, E_2F_3, E_1F_1 concur at y_1.
CA, F_3D_1, F_2D_2 concur at z_1.
x_1, y_1, z_1 lie on a line p.

71. AB, NP, I_1I_2 concur at x_2.
BC, PQ, I_2I_3 concur at y_2.
CA, QN, I_3I_1 concur at z_2.
(N, P, Q are the feet of the interior angle bisectors.)
x_2, y_2, z_2 lie on a line q.

72. The three lines n, p, q are concurrent.

73. A', B', C' are the midpoints of the sides of the triangle ABC. Lines drawn through A', B', C', respectively, parallel to the triads of angular transversals which determine Γ, Γ_1, Γ_2, Γ_3, concur at Γ', Γ_1', Γ_2' Γ_3'. Then $\Gamma\Gamma'$, $\Gamma_1\Gamma_1'$, $\Gamma_2\Gamma_2'$, $\Gamma_3\Gamma_3'$ are concurrent at the centroid of the triangle ABC.

74. $I\Gamma'$, $I_1\Gamma_1'$, $I_2\Gamma_2'$, $I_3\Gamma'_3$ concur at the symmedian point of the triangle ABC.

75. IQ, I_1Q_1, I_2Q_2, I_3Q_3 concur at the centroid of the triangle ABC.

(The propositions 65 to 75 inclusive are taken from Mackay's "Euclid" and his "Symmedians and Concomitant Circles.")

76. If DEF be the triangle formed by joining the inscribed points of contact of the triangle ABC; $D_1E_1F_1$ the triangle formed by joining the inscribed points of contact of the triangle DEF; $D_2E_2F_2$ the triangle formed by joining the inscribed points of contact of the triangle $D_1E_1F_1$; I, I_1, I_2, I_3 are the inscribed and escribed centres. I_1D, I_2E, I_3F concur at the homothetic centres of the triangles DEF and $I_1I_2I_3$. ID_1, I_3E_1, I_2F_1 concur at the homothetic centre of the triangles $D_1E_1F_1$ and II_3I_2, and so on. (Dr. Mackay, Proceedings Edinburgh Math. Soc., Vol. I, pp. 51–2.)

77. If three straight lines drawn from the vertices of a triangle are concurrent, the three lines drawn parallel to them from the midpoints of the opposite sides are also concurrent; and the straight line joining the two points of concurrency passes through the centroid of the triangle and is there trisected. (Frigier in Gergonne's Annales, Vol. VII, 170.)

78. If ABC be any triangle and O any point whatever, and A_1, B_1, C_1 be points symmetrical to O with respect to the midpoints of BC, CA, AB, then AA_1, BB_1, CC_1 concur at a point P. The centroid G lies on the line OP and divides it in a constant ratio. (M. d'Ocagne in Nouvelles Annales, Third Series I, 239.)

79. If through K (Grebe's Point) parallels to the sides BC, CA, AB of the triangle ABC are drawn, meeting these sides in D, D'; E, E'; F, F', respectively, and if EF and $E'F'$ intersect in p; FD and $F'D'$ in q; DE and $D'E'$ in r, then Ap, Bq, Cr are concurrent. (Dr. Mackay, "Symmedians of the Triangle," etc., p. 39.)

80. A', B', C' are the midpoints of the sides of the triangle ABC, and I, I_1, I_2, I_3, are the in and ex centers.

I_1A', I_2B', I_3C' concur at the symmedian point of the triangle $I_1I_2I_3$.

IA', I_3B', I_2C' concur at the symmedian point of the triangle II_3I_2.

I_3A', IB', I_1C' concur at the symmedian point of the triangle I_3II_1.

I_2A, I_1B', IC' concur at the symmedian point of the triangle I_2I_1I.

81. If AK, BK, CK cut the sides of the triangle ABC at the points R, S, T and the circumcircle of the triangle ABC at the points D, E, F, then

AK, BF, CE are concurrent.

BK, CD, AT are concurrent.

CK, AE, BD are concurrent.

82. X, Y, Z are the feet of the perpendiculars in the triangle ABC. If H_1, H_2, H_3 be the ortho-centers of the triangles AYZ, ZBX, XYC, then the lines H_1X, H_2Y, H_3Z are concurrent.

83. If H_1', H_2', H_3' be the ortho-centers of the triangles HYZ, XCZ, XYB.

H_1'', H_2'', H_3'' be the ortho-centers of the triangles CYZ, XHZ, XYA.

H_1''', H_2''', H_3''' be the ortho-centers of the trianglas BYZ, XAZ, XYH.

And if T_1 be the homothetic center of the triangles XYZ and $H_1'H_2'H_3'$.

T_2 be the homothetic center of the triangles XYZ and $H_1''H_2''H_3''$.

T_3 be the homothetic center of the triangles XYZ and $H_1'''H_2'''H_3'''$.

Then AT_1, BT_2, CT_3 concur at the centroid of the triangle XYZ.

(Nos. 80, 81, 82, 83 are extracted from the work of Dr. Mackay in the Proceedings of the Edinburgh Math. Soc.)

84. If through K parallels be drawn to BC, CA, AB, they intersect the corresponding altitudes in A_1, B_1, C_1, respectively, which are the vertices of Brocard's first triangle. BA_1, CB_1, AC_1 concur at Ω; BC_1, CA_1, AB_1 concur at Ω', and thus the two Brocard points are determined.

NOTE ON "NOTE ON SMITH'S DEFINITION OF MULTIPLICATION." BY A. L. BAKER.

The rule should be: To multiply one quantity by another, perform upon the multiplicand the series of operations which was performed upon unity to produce the multiplier.

This does not mean, perform upon the multiplicand the series of successive operations which was performed upon unity and upon the successive results.

Thus, to multiply b by $\sqrt{a}$: If we attempt to consider $\sqrt{a}$ as derived by taking unity a times and then extracting the square root of the result, we violate the rule. To get $\sqrt{a}$ by performing operations upon unity, we must (e. g., a=2) take unity 1 time, .4 times, .01 times, .004 times, etc., and add the results. Doing this to b, we get the correct result, viz., $\sqrt{2}\,b = 1.414\ldots b$.

The rule is thus universal, applying to all multipliers, complex, quaternion and irrational.

THE GEOMETRY OF SIMSON'S LINE. BY C. E. SMITH, INDIANA UNIVERSITY.

1. If from any point in the circumference of the circumcircle to a $\triangle$ ABC $\perp$s to the sides of the $\triangle$ be drawn, their feet, P_1, P_2, and P_3, lie in a straight line. This is known as Simson's Line.

(a) First proof that P_1, P_2, and P_3 lie in a straight line.

Since $\angle$s PP_3B and PP_1B (Fig. 1.) are both right $\angle$s, P, P_3, P_1 and B are concyclic.

Likewise P, P_2, A, and P_3 are concyclic.

Now $\angle PP_3P_1 + \angle PBP_1 = 180°$.

and $\angle PAC + \angle PBP_1 = 180°$.

$\therefore \angle PP_3P_1 = \angle PAC$,

But $\angle PAC + \angle PAP_2 = 180°$.

$\therefore \angle PP_3P_1 + \angle PAP_2 = 180°$.

But $\angle PAP_2 = \angle PP_3P_2$ (measured by same arc of auxiliary circle)

$\therefore \angle PP_3P_1 + \angle PP_3P_2 = 180°$, or a straight $\angle$.

$\therefore$ P_1 P_3 and P_2 lie in a straight line.

(b) **Second proof that P_1, P_2, and P_3 lie in a straight line.**

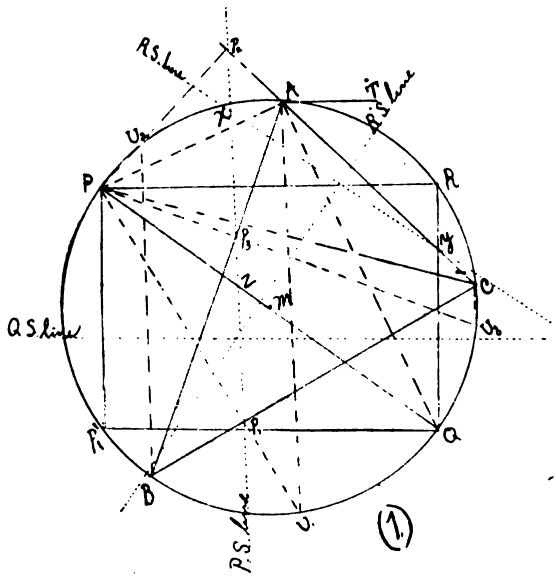
Draw PC and PA (Fig. 1).

Now $\angle$s PP_2C and PP_1C are right $\angle$s.

$\therefore$ P, P_1, C and P_2 are concyclic with PC as diameter.

$\angle PAB = \angle PCB = \angle PCP_1$,

and $\angle PP_2P_1 = \angle PCP_1$,



$\therefore \angle PAB = \angle PAP_3 = PP_2P_1$

Now P, P_2, A, P_3 are concyclic.

$\therefore \angle PP_2P_3 = PAP$ and

$\therefore \angle PP_2P_3 = \angle PP_2P_1$

$\therefore$ P_2P_1 passes through P_3 and the three points are collinear.

2. If PP_1 be produced until it intersects the circumcircle of $\triangle$ ABC, at the point U_1, then AU_1 is $\parallel$ to Simson's line of P. (Fig. 1.)

Now the points P, P_1, P_2, and C are concyclic.

$\therefore$ the $\angle P_1PC = \angle P_1P_2C$.

But $\angle P_1PC = \angle U_1AC$, (arc CU_1 common to both)

and $\angle P_1P_2C = U_1AC$.

If two angles are equal and have a pair of sides in coincidence, then the other sides must also either coincide or be parallel. Hence AU || $P_1 P_2 P_3$, or to Simson's line. Thus we can show BU_2 and CU_3 parallel to Simson's line of P and therefore AU_1, BU_2 and CU_3 are parallel to each other.

3. Let AT (Fig. 1) be isogonal conjugate to AP. Then Simson's line of P $\perp$ AT.

Also Simson's line of T $\perp$ AP.

Now, AU_1 is || Simson's line of P, and

$\angle BAT = \angle PAC = 180° - \angle PU_1C$.

Also $\angle BAU_1 = \angle BCU_1$.

$\therefore \angle BAT - \angle PAU_1 = 180° - \angle PU_1C - \angle BCU_1$.

$\therefore U_1AT = 180° - 90° = 90°$ for $\angle PU_1C$ is measured by $\frac{1}{2}$ arc PC and $\angle BCU_1$ is measured by $\frac{1}{2}$ arc BU_1.

But PP_1C, which is a right $\angle$, is measured by $\frac{1}{2}$ arc $(PC + BU_1)$.

$\therefore U_1A \perp$ AT and so Simson's line of P must be. In like manner we can prove Simson's line of T $\perp$ AP.

Now, if Q is the point on the circumference opposite P, then AU_1 and AQ are isogonal conjugate lines, for

$\angle U_1AT = \angle QAP = 90°$ and

$\angle TAC = \angle BAP$ with $\angle U_1AQ$ common.

$\therefore \angle U_1AT - \angle QAU_1 - \angle TAC = \angle QAP - \angle U_1AQ - \angle BAP$.

$\therefore \angle BAU_1 = \angle CAQ$.

4. If P and Q are opposite points on the circumference, their Simson's lines are $\perp$ to each other.

Now, the isogonal conjugate of AP is $\perp$ to isogonal conjugate of AQ, and, therefore, since the Simson's line of P || AU_1 and the Simson's line of Q || AT, the Simson's line of P will be $\perp$ to Simson's line of Q.

5. A side, BC, and its altitude in a triangle are the Simson's lines of A′ and A, respectively, where A′ is the point on the circumference opposite A. (Fig 4.)

Since the feet of the $\perp$s from A to AB and AC coincide with A, and the foot of the $\perp$ from A to BC is H_a, therefore the Simson's line of A is AH_a. Again, the feet of $\perp$s from A′ to the sides AB, AC, and BC are B, C, and A'_a, respectively; hence BC is the Simson's line of A′.

Since AH_a, BH_b and CH_c are the Simson's lines of A, B, and C, respectively, their Simson's lines concur in H, the ortho-center.

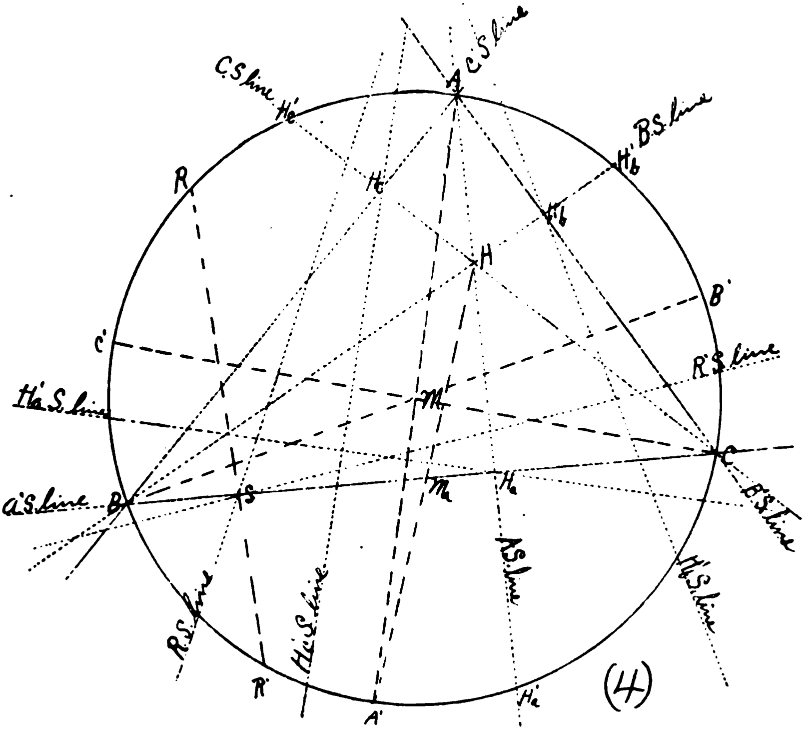
6. Let A′, B′ and C′ be the points on the circumference opposite A, B and C, respectively, and H_a', H_b', and H_c' be the points where AH_a, BH_a and CH_a, produced, cut the circumference, then the

Simson's lines of A, B′ and C′ concur in A,

Simson's lines of B, C′ and A′ concur in B, and

Simson's lines of C, A′ and B′ concur in C,

Also, since the Simson's line of H_a', H_b' and H_c' must pass through H_a, H_b and H_c, respectively, we have the



Simson's lines of A, A′ and H_a' concurring in H_a,

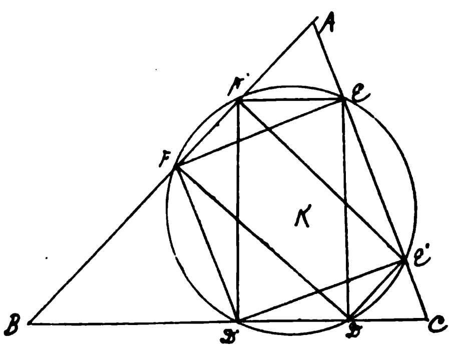
Simson's lines of B, B′ and H_b concurring in H_b and

Simson's lines of C, C′ and H_c' concurring in H_c.

Since the point of concurrency of the Simson's lines of the extremities of a chord ⊥ to BC is the point where this chord intersects BC, it follows that the Simson's lines of the extremities of all chords ⊥ to BC are concurrent with Simson's line of A′; the Simson's lines of extremities of all chords ⊥ AC are concurrent with Simson's line of B′; and the Simson's lines of the extremities of all

chords $\perp$ AB are concurrent with Simson's line of C′. Thus there is a triple infinity of sets of three points on the circumcircle, the points of concurrency of the Simson's lines of which lie in the sides of the fundamental triangle.

7. Since, in the cosine circle (Fig. 6), F′ EDD′, FEE′ D′, and FF′ E′ D are all rectangular, it follows at once that the Simson's line of D′, with regard to rt. △ DEF, is FD, of E′, DE and of F′, EF. Also Simson's line of D, with regard to rt. △ D′E′F′, is D′ E′, of E, E′ F′ and of F, F′D′.



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8. In Fig. 2, M_a, M_b, M_c are the midpoints of the sides of fundamental triangle opposite A, B, and C, respectively. H_a'', H_b'', H_c'' are the midpoints of AH, BH and CH, respectively, where H is the ortho-center.

Now $M_bA = M_bH_a$.

$\therefore\ \angle M_bH_aA = \angle M_bAH_a$.

Likewise $\angle M_cH_aA = \angle M_cAH_a$.

$\therefore\ \angle M_cH_aM_b = \angle A$.

We also know $\angle M_cM_aM_b = \angle A$.

$\therefore$ M_c, M_b, M_a and H_a are concyclic.

In the same way we can show

M_c, M_b, M_a and H_b and M_c, M_b, M_a, and H_c to be concyclic.

$\therefore$ Since three points determine a circle, these six points are all concyclic.

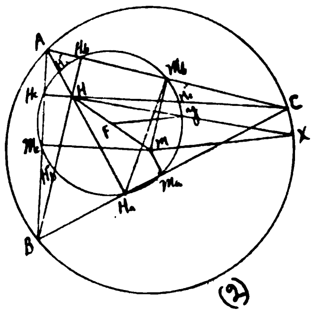
Now H_a, H_b, H_c are the feet of the altitudes of △ AHB.

But we have just shown that, in any triangle, the feet of its altitudes and the midpoints of its sides are all concyclic.

$\therefore$ H_a, H_b and H_c and H_a'', H_b'', and H_c'' are concyclic.

Then, since three points determine a circle, M_a, M_b, M_c, H_a, H_b, H_c, H_a'', H_b'' and H_c'' must all lie on the same circle. This circle, since it passes through nine definite points, is called the ***nine-point*** circle.

A $\perp$ to the midpoint of $H_a M_a$ meets HM at its midpoint, say F. So $\perp$s to $H_b M_b$ and $H_c M_c$ at their midpoints meet HM in F.



$\therefore$ F, the midpoint of HM, is the centre of the nine-point circle.

Since it is the circumcircle of rt. $\triangle$ $M_aM_bM_c$, which has just half the dimensions of $\triangle$ ABC, its radius will be just half the radius of the larger circle.

9. The nine-point circle bisects any line drawn from H to the circumcircle of the fundamental triangle.

Let MX and FY be any two $\parallel$ radii of the two circles. Now, since F is the mid-point of MH and $FY = \frac{1}{2} MX$, HYX is a straight line with Y as its midpoint.

10. Simson's line of P bisects PH. (Fig. 7.)

Let us suppose that D is the midpoint of PH. Then D lies on the nine-point circle. Then we must prove it lies on $P_1 P_2$.

Since $P P_1$ and AH are $\perp$ to BC, they are $\parallel$. Also since D is midpoint of PH, $\triangle$ P, DH_a is isosceles. Let E be midpoint of AH. Then $DE = \frac{1}{2} AP$.

D, E, and H_a are on the nine-point circle.

A, P, and C are on the circumcircle.

Then since $DE = \frac{1}{2}$ AP and radius of nine-point circle $= \frac{1}{2}$ R, $\angle$ EH_a D, inscribed in nine-point circle, $= \angle$ ACP, inscribed in circumcircle.

$\angle EH_a D = \angle ACP = \angle DP_1 P$.

Let the intersection of P_1 D and AC be P_2,

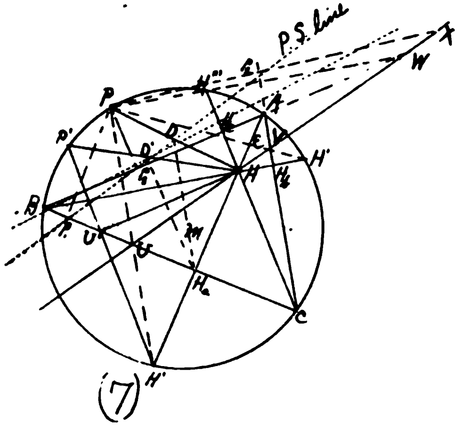
Then $\angle PP_1 D = \angle ACP = \angle PCP_2$,

$\therefore$ P, P_1, C, and P_2 are concyclic and $\therefore$ $\angle PP_2C = \angle PP_1C = 90°$ and $PP_2 \perp AC$.

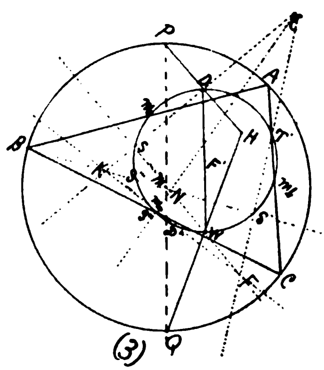
$\therefore$ P_1 D is Simson's line of P.

The point where PH cuts Simson's line of P is called its *center*.

11. The line joining A′, the point opposite the vertex A of $\triangle$ ABC (Fig. 4), with H, the ortho-centre, bisects the side BC.



For, the Simson line of A′ is BC, $\therefore$ BC bisects A′ H, and, as we have shown, this bisection is on the nine-point circle. But the nine-point circle cuts BC at two places only, at H_a and M_a; hence it is obvious that A′ H passes through M_a, and thus it bisects BC.



12. S, the intersection of the Simson lines of P and Q, the extremities of any diameter of the circumcircle, lies on the nine-point circle. (Fig. 3.)

Take W as the midpoint of QH and D of PH. Then they are both on the nine-point circle and WD must be its diameter, since it is $\parallel$ and equal to $\frac{1}{2}$ QP. Then, as $\angle$ S is a right $\angle$, S must also lie on the nine-point circle. S is called the *vertex* of either Simson line.

13. H', H'' and H''' (Fig. 7) are the points on the circumcircle through which AH, BH and CH, respectively, pass.

U is the point where PH' cuts BC.

V is the point where PH'' cuts AC.

W is the point where PH''' cuts AB.

Now, U, V, H and W lie on a straight line $\parallel$ to the Simson line of P.

$\angle VHH_b = \angle VH''H_b$, ($H_b$ is midpoint of HH''.)

$\qquad = \angle PH''B = \angle PCB.$

$\angle UHH_a = UH'H_a = \angle PH'A = \angle PCA.$

Also H, H_a, C, and H_b are concyclic.

$\therefore \angle H_aHH_b + \angle C = 180°.$

But we have just proven $\angle VHH_b + \angle UHH_a = \angle C.$

$\therefore \angle H_aHH_b + \angle VHH_b + UHH_a = 180°$, and

$\therefore$ U, H and V are collinear.

Now, $\angle WHH''' = WH'''H = 180° - \angle PH'''C.$

$\qquad = \angle B + \angle UH'H.$

$\qquad = \angle B + \angle UHH'.$

Also B, H_a, H, and H_c are concyclic.

$\therefore \angle B + \angle H_aHH_c = 180°$ and

$\therefore \angle B + \angle UHH' + \angle H_cHU = 180°.$

So then $\angle WHH''' + \angle H_cHU = 180°$, which proves W, H and U collinear.

Therefore all four points, W, V, H and U must be collinear.

Now, PP_2 is $\parallel$ to HH'', for both are $\perp$ to AC.

$\therefore \triangle$ PVX is isosceles, and $PP_2 = P_2X$.

Now, $\angle P_2XV = \angle PCP_1$ and P, P_2, C, and P_1 are concyclic.

$\therefore \angle PP_2P_1 = \angle PCP_1 = \angle P_2XV.$

$\therefore P_1P_2P_3$ is $\parallel$ to UVW.

From this we can also see that Simson's line of P bisects all lines from P to the line WVHU.

14. The angle between the Simson lines of two points P and P′ is equal to an $\angle$ inscribed in the circumcircle with PP′ an arc and also to an angle inscribed in the nine-point circle with arc equal to the part of the circumference included between the centers of their Simson's lines.

Draw $P'H'$ (Fig. 7), letting it cut BC in U'. Then, from above proposition, $HU' \parallel$ to Simson's line of P'. Also $HU \parallel$ to Simson's line of P.

$\therefore \angle (S, S') = \angle (HU, HU')$. Now, H is the center of similitude of the circumcircle and the nine-point circle. Draw $P'H$, letting it cut the Simson line of P' at D'.

Then P and D, P' and D' and H' and H_a are corresponding points.

$\therefore H_aD$ and H_aD' and $H'P$ and $H'P'$ are $\parallel$ lines, whence $\angle DH_aD' = \angle PH'P' = \angle U'HU$.

15. If P and Q (Fig. 1) be the extremities of a diameter and R and R' two other opposite points such that PR and QR' are $\perp$ to Simson's line of P and PR' and QR are $\perp$ to Simson's line of R, then the Simson's line of R is parallel to PQ and Simson's line of R' is $\perp$ to PQ.

Since the angle between the Simson's lines of two points is equal to an angle inscribed in the arc between them, we know that $\angle ZXY = \angle YQZ$. Also $ZX \parallel QY$.

$\therefore$ QZXY is a parallelogram, and XY, the Simson's line of R, is $\parallel$ to PQ. Then it follows that Simson's line of R is $\perp$ to PQ, since it is conjugate to Simson's line of R.

16. If ES and FS (Fig. 3) are the Simson's lines of opposite points on the circumcircle, and EF be any other Simson's line, then $T'E = T'F = T'S$, where T' is the center of the last named Simson's line.

$\angle T'ED = \angle T'SD$ (a previous proposition).

$\therefore T'E = T'S$. In like manner we can show $T'F = T'S$. $\therefore T'E = T'F$.

The Simson's lines of opposite points on the circumcircle are said to be *conjugate.*

17. The arc between the vertices of two Simson's lines (not conjugate) is twice as large as the arc between their centers. For $ET'S$ is an isosceles $\triangle$ and $\angle ET'S = 2\ T'ST$. But $ET'S = S'T'S$. $\therefore$ arc $SS' = 2$ arc $T'T$. Now suppose $T'S$ is less than R (it never can be greater), then S'' could be another point on the nine-point circle such that $T'S'' = T'S$ and $\angle ES''F$ would also be a right $\angle$. It is thus evident that there are always two pairs of conjugate Simson's lines passing through E and F.

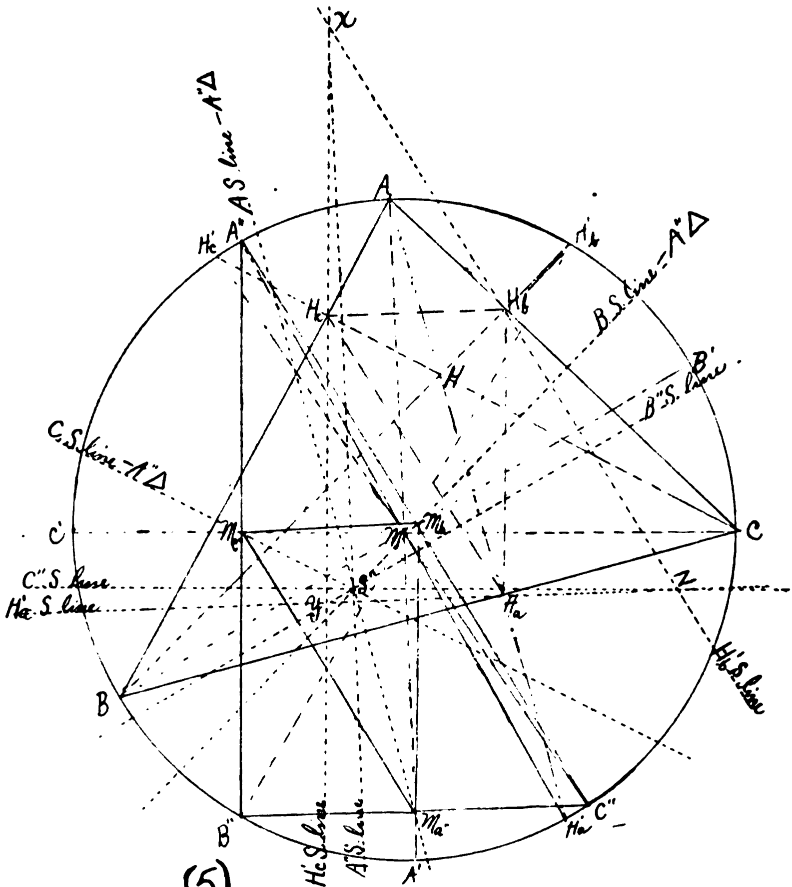
The limit of EF is 2R.

For when S and S'' coincide at S''', $T'S''' = T'E = T'F = r$. In this case we have but one pair of conjugate Simson's lines.

18. If two Simson's lines, SD and $S''D''$, which are not conjugate, cut a third Simson's line, $T'S'$, at equal distances, E and F, from its center, T', then

the line joining the point of intersection, K, of SD and S″D″ with S′, the vertex of T′S′ is a Simson's line conjugate to T′S′.

Let ES and FS″ intersect at K, and ES″ and FS intersect at N (Fig. 3). Since the pair of lines, ES, FS and ES″, FS″ are conjugate Simson's lines, they



(5)

are ⊥ to each other, or ES″ and FS are altitudes in the △ EKF. Therefore KN is the third altitude, and we may prove S′ to be the foot of this altitude on EF.

The nine-point circle of the △ ABC passing through the feet, S and S″, of the two altitudes, and through the middle point, T′, of one side of the △ EKF, must

be also the nine-point circle of the $\triangle$ EKF, and therefore the second intersection of the nine-point circle with the side, EF, must be the foot of the altitude to EF, or KS′.

Hence S′ is the foot of the altitude KN. But any side and its altitude is a pair of conjugate Simson's lines, and since EF is a Simson's line of a point on the circumcircle of ABC, KN is the Simson's line conjugate to EF.

Any triangle like EKF formed by three Simson's lines, the altitudes of which are Simson's lines conjugate to the sides, and having the nine-point circle in common with the triangle ABC, we shall call a *Simson Triangle.*

Since the nine-point circle is common to both triangles ABC and EKF, the radius of the nine-point circle is one-half the radius of the circumcircle of either triangle; therefore the radius of the circumcircle of any Simson triangle is equal to the radius of the circumcircle of the original triangle.

19. The common vertex S‴ of the pair of limiting Simson's lines belonging to TS is on the same straight line as K, N and S′. For, since T′S‴ is a diameter of the nine-point circle, $\angle$ T′S′S‴ $= 90°$, or S′S‴ $\perp$ to EF. $\therefore$ S‴ is on the altitude KS′.

20. A″, B″ and C″ are points on the circumference opposite H_a', H_b' and H_c' respectively. (Fig. 5.) Prove that the Simson's lines of A″, B″, and C″ are $\parallel$ respectively to AA′, BB″ and CC″ and that they are $\perp$ respectively to B″C″, A″C″, A″B″. Now the angle between the Simson's lines of A and A″ will be equal to an angle measured by $\frac{1}{2}$ arc AA″. But the angle between AA′ and AH_a, the Simson's line of A, is measured by an arc equal to this. Therefore Simson's line of A″ is $\parallel$ to AA′. So the Simson's line of B″ is $\parallel$ to BB′ and Simson's line of C″ $\parallel$ to CC′.

Now arc H_b' CB″ $=$ arc H_c' BC″ $= 180°$.

$\therefore$ arc H_b' CC″ $=$ arc H_c' BB″

$\therefore$ H_b' H_c' $\parallel$ B″ C″, also H_b' H_a' $\parallel$ A″ B″ and

H_a' H_c' $\parallel$ A″C″. Therefore $\triangle$ A″ B″ C″ is equivalent to $\triangle$ H_a' H_b' H_c', being inscribed in same circle and having sides equal and parallel.

$\angle$ H_c'CA $=$ $\angle$ H_b' BA. (From similarity of $\triangle$s ABH_b and ACH_c).

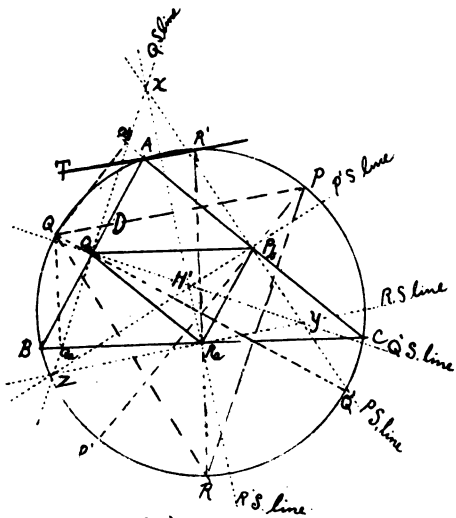
$\therefore$ arc $AH_b' =$ arc AH_c', $\therefore$ since AA′ is a diameter it must be $\perp$ to chord H_c' H_b' and therefore to B″ C″. So we may prove BB′ $\perp$ A″ C″ and CC′ $\perp$ A″ B″.

21. The Simson's lines of H_a' H_b' H_c' form a Simson's triangle XYZ of which the Simson's lines of A″, B″, C″ are the altitudes, A″, C″, B″ being points opposite H_a', H_b', H_c' respectively.

Let Simson's lines of H_b', H_c', and H_c', H_a' and H_a', H_b' concur in X, Y, and Z respectively.

The Simson's lines of A'' and H_a', of B'' and H_b', and of C'' and H_c' are conjugate, therefore their intersections, u, v, and w will lie on the nine-point circle of rt △ ABC. The Simson's lines of H_a', H_b' and H_c' must pass through H_a, H_b, H_c respectively and therefore rt △ XYZ must have the same nine-point circle as △ ABC. Now since H_a, H_b and H_c can not be the feet of altitudes they must be the midpoints of the sides and therefore u, v and w must be the feet of altitudes.

Thus the four points of concurrency are established, namely X, Y, Z and S''. S'', being formed by the intersection of the altitudes of △ XYZ, is the orthocenter of the same.



(8)

22. If R, P and Q (Fig. 8) be taken as the midpoints of arcs BC, AC and AB, respectively, and R′, P′ and Q′ be the points on the circumference opposite R, P, and Q, then the Simson's lines of R, P, and Q will form a △ XYZ, the altitudes of which will be the Simson's lines of R′, Q′ and P′.

It may be assumed that XYZ is the triangle formed by the intersection of the Simson lines of R, P and Q. That the Simson's line of Q′ is the altitude on side XZ may be established thus:

$\angle AQ_bQ_c = \angle A - \angle AQ_cQ_b.$

But, since Q, Q_c, A, and Q_b are concyclic, $\angle AQ_bQ_c = \angle AQQ_c$, which is measured by $\frac{1}{2}$ arc AQ′.

Also, since Q, B, Q_a, and Q_c are concyclic, $\angle BQQ_c = 180° - \angle BQ_aQ_c$.

$\therefore \angle Q_cQ_aC = \angle BQQ_c$, which is measured by $\frac{1}{2}$ arc BQ′. But arc BQ′ = arc AQ′.

(A.) $\therefore \angle AQ_bQ_c = \angle CQ_aQ_c$.

$$\text{But } \angle AQ_bQ_c = \angle A - \angle AQ_cQ_b, \text{ and}$$
$$\angle CQ_aQ_c = \angle B + \angle BQ_cQ_a.$$
$$= \angle B + \angle AQ_cQ_b.$$

Now the Simson's line of Q′ is $\perp$ to Q_bQ_a the Simson's line of Q, at Q_c, and $\angle AQ_cP_b = \angle B$ and $\angle BQ_cR_a = \angle A$. And from (A.) we know that $\angle Q_bQ_cP_b = \angle Q_aQ_cR_a$, $\therefore \angle P_bQ_cH'$, $= \angle R_aQ_cH'$ and thus Simson's line of Q′ is proven to be the internal bisector of $\angle Q_c$ in rt. $\triangle R_aP_bQ_c$. In like manner the Simson's line of R′ may be proven to be the internal bisector of $\angle R_a$, and Simson's line of P′, the internal bisector of $\angle P_a$ of same triangle. Since the Simson's lines of Q, R, and P are $\perp$ to these internal bisectors at the vertices of the $\triangle$, they must be the external bisectors of the same angles. But we know that the internal and external bisectors of the $\angle$s of a triangle concur in four points. Thus X, Y, Z and H′ are each points of concurrency of three Simson's lines. H′, of course, is the ortho-center of $\triangle$ XYZ.

23. $\triangle$ XYZ has the same nine-point circle as $\triangle$ ABC and is therefore inscribable in the same sized circle as rt. $\triangle$ ABC.

That it has the same nine-point circle follows easily from the fact that three points that must lie on its nine-point circle, the feet of its altitudes, are coincident with three points on the ABC nine-point circle, the midpoint of its sides. Since three points determine a circle, their nine-point circles must be identical.

24. The Simson's line of P is $\parallel$ to RQ, Simson's line of R is $\parallel$ to PQ, and Simson's line of Q is $\parallel$ to RP.

The Simson's line of R will be $\perp$ to Simson's line of R′, so let us prove Simson's line of R′ $\perp$ to PQ′.

Now, the Simson's line of R′ will be $\perp$ to the line isogonal conjugate to AR′ which we call AT. Then let us prove AT $\parallel$ to PQ.

To be $\parallel$ $\angle$ ADP must $= \angle$ CAR′.

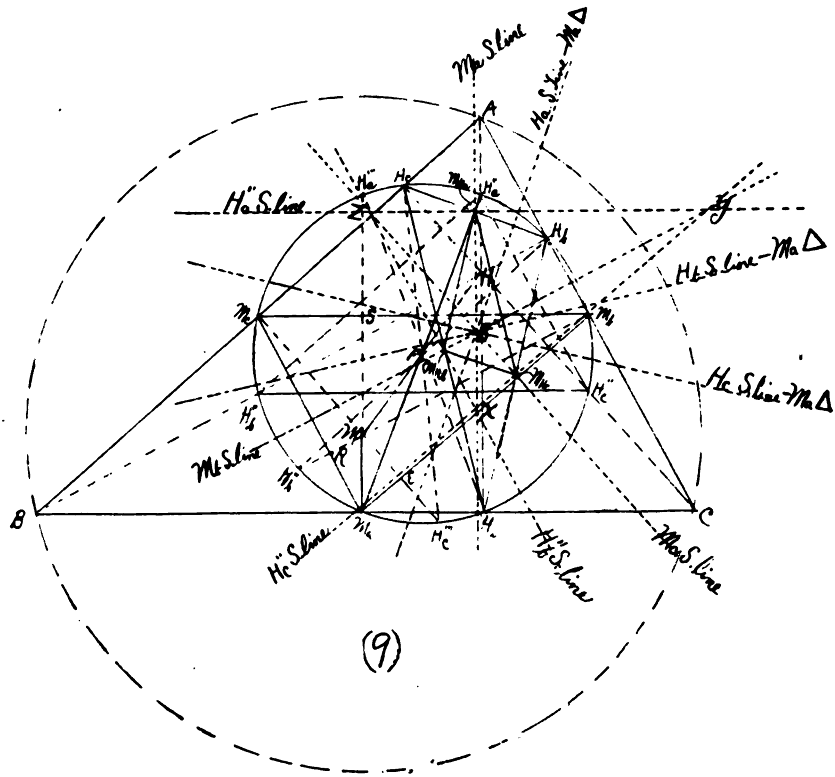
$\angle$ ADP is measured by $\frac{1}{2}$ arc (AP + BQ).

$\angle$ CAR′ is measured by $\frac{1}{2}$ arc CR′.

Arc AP = arc CP, and $\frac{1}{2}$ arc BQ measures $\frac{1}{2} \angle$ C.

Now, $\angle\ PRR' = 90^\circ - PR'R.$
$$= 90^\circ - \tfrac{1}{2}(A + B).$$
$$= \tfrac{1}{2}\,C.$$

$\therefore$ arc $BQ =$ arc PR', and so $\angle\ ADP = \angle\ CAR'$. Hence AT is $\parallel$ PQ and $\therefore$ Simson's line of R is $\parallel$ to PQ. In like manner we may prove Simson's line of P $\parallel$ to RQ, and Simson's line of Q $\parallel$ to RP.



25. The Simson's lines of H_a'', H_b'', H_c'' (Fig. 9) with respect to $\triangle$ $H_aH_bH_c$, inscribed in the nine-point circle, form a rt. $\triangle$ XYZ, the altitudes of which are the Simson's lines of M_a, M_b and M_c with respect to the same rt. $\triangle$.

H, the orthocenter of $\triangle$ ABC, is the incenter of $\triangle$ $H_aH_bH_c$, for $\angle$s AH_cH and AH_bH being right $\angle$s, A, H_c, H and H_b are concyclic with AH as diameter.

H_a'', being midpoint of AH, is the center and therefore chord $H_a''H_b$ = chord $H_a''H_c$. Therefore H_aH_a'' bisects $\angle H_a$, H_bH_b'' bisects $\angle H_b$, and H_cH_c'' bisects $\angle H_c$.

H_a'', H_b'' and H_c'' are points on the nine-point circle opposite M_a, M_b, M_c, respectively, for, since MM_a and H_aH_a'' are $\parallel$ and the center of the nine-point circle is F, the midpoint of MH, a line from M_a through F, will meet AH_a on the circumference of the nine-point circle, necessarily at H_a''. In like manner H_b'' can be shown to be opposite M_b, and H'' opposite M_c.

This proves $H_a''H_b''$ $\parallel$ to M_aM_b and equal to it, and therefore $\parallel$ to AB, $H_b'H_c'$ equal to M_bM_c and parallel to both M_bM_c and BC, and $H_c''H_a''$ equal to M_cM_a and parallel to both M_cM_a and CA.

Now, the Simson's line of M_a will be $\perp$ to BC and $\parallel$ to AH_a, for H_aC is isogonal conjugate to H_aM_a since AH_a bisects $\angle H_bH_aH_c$, thus making $\angle CH_aH_b = \angle M_aH_aH_c$. Therefore the Simson's line of H_a'', since it is conjugate to Simson's line of M_a, is $\parallel$ to M_cM_b, $H_b''H_c$ and BC. In like manner we can prove the Simson's line of $M_b \perp$ AC and $\parallel$ to BH_b and, therefore, the Simson's line of H_b'' $\parallel$ to M_aM_c, $H_c''H_a''$ and AC; and Simson's line of $M_c \perp$ AB and $\parallel$ to CH_c and, therefore, the Simson's line of H_c'' $\parallel$ to M_aM_b, $H_b''H_a''$ and AB.

Now $\triangle M_{Ha}M_{Hb}M_{Hc}$ is oppositely similar to $\triangle H_aH_bH_c$. Also, from what we have proven before, the Simson's lines of M_a and H_a'' must both pass through M_{Ha}. Then the Simson's line of M_a being $\parallel$ to AH_a, will bisect $\angle M_{Hb}M_{Ha}M_{Hc}$. In like manner we can show that the Simson's lines of M_b and M_c bisect $\angle$s $M_{Ha}M_{Hb}M_{Hc}$ and $M_{Ha}M_{Hc}M_{Hb}$. Now the Simson's lines of H_a'', H_b'' and H_c'' are $\perp$ to Simson's lines of M_a, M_b and M_c, respectively, and therefore they are the external bisectors of the $\angle$s of the rt. $\triangle M_{Ha}M_{Hb}M_{Hc}$. Since the internal and external bisectors of a $\triangle$ meet by threes in four points, we may conclude the Simson's lines of M_a, H_b'', and H_c'' concur in X, Simson's lines of M_b, H_c'', and H_a'' concur in Y, Simson's lines of M_c, H_a'', and H_b'' concur in Z, and Simson's lines of M_a M_b M_c concur in S'''. S''', we see, is the orthocenter of $\triangle$ XYZ and in-center of $\triangle M_{Ha}M_{Hb}M_{Hc}$.

$\triangle$ XYZ has its sides $\parallel$ to sides of $\triangle M_aM_bM_c$ and oppositely $\parallel$ to $\triangle$s $H_a''H_b''H_c''$ and ABC.

26. Let us prove $\triangle$ XYZ equivalent to $\triangle$s $M_aM_bM_c$ and $H_a''H_b''H_c''$ and, therefore, inscribable in the nine-point circle.

$\triangle M_{Ha}M_{Hb}M_{Hc}$ bears the same relation to $\triangle$ XYZ that $\triangle H_aH_bH_c$ does to $\triangle$ ABC. Therefore, since $\triangle M_{Ha}M_{Hb}M_{Hc}$ is $\frac{1}{4}$ the size of $\triangle H_aH_bH_c$, $\triangle$ XYZ must be $\frac{1}{4}$ the size of rt. $\triangle$ ABC and thus equivalent to $\triangle M_aM_bM_c$, and rt. $\triangle H_a''H_b''H_c''$ and hence inscribable in the nine-point circle of the fundamental $\triangle$.

27. If $H_a'''H_b'''H_c'''$ are the points on the nine-point circle opposite H_a H_b and H_c respectively, then the Simson's lines of M_c, H_c'', and H_c''' concur in M_{Hc}, for H_a H_b is Simson's line of H_c'''. Likewise the Simson's lines of M_b, H_b'' and H_b''' concur in M_{Hb} and the Simson's lines of M_a, H_a'', and H_a''' concur in M_{Ha}.

28. Now considering $M_a M_b M_c$ as the reference $\triangle$ in the nine-point circle, let us prove that the Simson's lines of these same points, *i. e.*, M_c, H_c'' and H_c''', etc., concur.

Chord M_c H_c''' is $\parallel$ H_c H_c'' and $\therefore$ $\perp$ to $M_a M_b$. This is true because $\angle$ H_c M_c H_c''' is a right $\angle$.

The Simson's line of M_c will be this chord M_c H_c''', the Simson's line of H_c''' will pass through E, the foot of this altitude, and the Simson's line of H_c'' will be side $M_a M_b$ since it is a point opposite the vertex M_c.

So, also, the Simson's lines of M_b, H_b'' and H_b''' will concur in R, and the Simson's lines of M_a, H_a'', and H_a''' concur in S.

29. Now by noticing the lettering and arrangement of (Fig. 17) it will be seen that H_a''', H_b''' and H_c''' correspond to H_a', H_b' and H_c' of that figure, and that H_a, H_b, and H_c correspond to A'', B'', and C'' of that figure. Therefore we know at once that the Simson's lines of H_a, H_b and H_c and of H_a''', H_b''' and H_c''' concur just as in that case by threes in four different points, the point of concurrency of H_aH_b and H_c being the ortho-center S''' of the triangle formed by the intersection of the Simson's lines of the other three points.

30. Also since $\triangle$ $H_a''H_b''H_c''$ and points H_a, H_b and H_c bear the same relation to the nine point circle that $\triangle$ ABC as points H_a', H_b', and H_c' do to the circle in Fig. 5, it follows at once that what was true of the Simson's lines of those points is also true of these.

Depending upon this same comparison between Figs. 5 and 9 it follows that the Simson's lines of points A, B and C in Fig. 5 concur at in-center of rt. $\triangle$ $M_{a''}M_{b''}M_{c''}$.

31. Now let us prove that S'' (Fig. 5), the point of concurrency of Simson's lines of A'', B'', C'', is also the in-center of $\triangle$ $M_{a'}M_{b''}M_{c''}$.

We have already proven that the Simson's lines of H_a', H_b' and H_c' form a Simson triangle XYZ, of which the Simson's lines of A'', B'' and C'' are the altitudes, and that $\triangle$ XYZ, is equivalent to $\triangle$ $A''B''C''$ with their sides respectively $\parallel$. Now, since H_a, H_b and H_c are the midpoints of the sides of $\triangle$ XYZ, $\triangle$ $H_aH_bH_c$ will be equal in every respect and similarly placed to $\triangle$ $M_{a''}M_{b''}M_{c''}$. We have also proven H to be the in-center of this $\triangle$ $H_aH_bH_c$. Again, since the Simson's lines of A'', B'' and C'' bisect A'' H, B'' H and C'' H, respectively, it is

clear that if $\triangle$ XYZ were to be given the rank of rt. $\angle$ A″B″C″ and a new one were to be formed from it, as it is formed from $\angle$ A″B″C″, then the point S″ would fall upon H. Therefore, since H is the in-center of $\triangle H_aH_bH_c$, S″ must be the in-center of $\triangle M_{a''}M_{b''}M_{c''}$.

Therefore we see that the six Simson's lines, three with reference to one $\triangle$ and three with reference to the other, meet in the same point.

32. This, at the same time, establishes another even more interesting proposition, namely: If the Simson's lines of the vertices of a first $\triangle$ with reference to a second $\triangle$ concur in a point S″, then the Simson's lines of the vertices of the second $\triangle$ with reference to the first $\triangle$ concur in the same point S″.

The broad scope covered by this proposition would enable me to double in number the points of concurrency of Simson's lines, but there would be little benefit in merely pointing them out, as the interested reader can easily see them for himself.

A Bibliography of Foundations of Geometry. By Morton Clark Bradley.

Euclid's treatment of parallels and angles and his definitions and axioms—particularly his twelfth—are the points of controversy that cause the most discussion. For nearly twenty centuries Euclid's work remained unquestioned. Since John Kepler's day, however, there have been new theories constantly advanced, theories built on axioms and definitions, a part of which, at least, are different from those of Euclid. The most important of the non-Euclideans are John Bolyai, Lobatschevski, Helmholtz, Riemann, Clifford, Henrici, Caley, Sylvester and Ball. The most prominent exponent of the non-Euclidean ideas in this country is Prof. Geo. Bruce Halsted, of Texas University. These mathematicians hold that Euclid's twelfth axiom is not, strictly speaking, an axiom—that it is not "a self-evident and necessary truth," but that it requires demonstration. They claim, too, that his definitions are not sufficient nor necessarily intelligible. Some of these men have built up new theories upon their substituted axioms and definitions, retaining those of Euclid that fit their theories. A few of these "reform" works are mere quibbles on words, but others deserve the serious consideration of all interested in pure geometry.

The list following is a complete list of English references to be found in the mathematical library of the University of Indiana or in the private

library of Dr. Aley. Chrystal says the bibliography credited to Mr. Halsted contains all the references up to its time, save one, giving the non-Euclidean arguments. The list is not complete in arguments for Euclid, it being impossible to enumerate all the editions of Euclid, edited and upheld by the different mathematicians. The list is complete enough, however, to assure the reader that there are arguments for Euclid as well as against him.

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Point-Invariants for the Lie Groups of the Plane.

By David A. Rothrock.

Among the many interesting and important applications of Lie's Theory of Transformation Groups none deserves more prominent mention than the application to invariant theory. Whether the invariants dealt with be functions or equations, surfaces and curves or points, equally interesting results are obtained. The present paper has to do with the determination of the point-invariants for the finite continuous groups of the plane as classified by Lie in Vol. XVI. of the Mathematische Annalen. In the first part of the paper is sketched a brief outline of the Lie theory leading up to the point-invariant, then follow the calculations of the invariant functions.

An infinitesimal point-transformation gives to x and y the increments

$$\delta x = \xi(x, y)\, \delta t, \quad \delta y = \eta(x, y)\, \delta t,$$

respectively, where δt is an infinitesimal independent of x and y. Such infinitesimal transformations move a point x, y through a distance

$$\sqrt{\delta x^2 + \delta y^2} = \sqrt{\xi^2 + \eta^2} \cdot \delta t,$$

and in a direction given by

$$\delta y : \delta x = \eta : \xi.$$

The variation of any function ϕ (x, y) by this infinitesimal transformation is given by

$$\delta\phi = \frac{d\phi}{dx}\delta x + \frac{d\phi}{dy}\delta y = \left\{ \xi (x, y) \frac{d\phi}{dx} + \eta (x, y) \frac{d\phi}{dy} \right\} \delta t.*$$

The variation of a function f (x, y) may be taken as a definition of an infinitesimal transformation; in the Lie notation we have an infinitesimal transformation defined by

$$Xf \equiv \xi (x, y) \frac{df}{dx} + \eta (x, y) \frac{df}{dy}.$$

If a function ϕ (x, y) is to remain invariant by the operation X f, then the variation

$$\delta \phi (x, y) = X \phi . \delta t$$

must vanish. Hence, a function ϕ (x, y) invariant by the infinitesimal transformation Xf is determined as a solution of the linear partial differential equation

$$Xf \equiv \xi (x, y) \frac{df}{dx} + \eta (x, y) \frac{df}{dy} = 0.$$

The infinitesimal transformation X f may be *extended* to include the increments of the co-ordinates of any number of points x_i, y_i, (i = 1, 2 .... n). We shall write this extended transformation thus:

$$W f = \sum_1^n i X^{(i)} f \equiv \sum_1^n i \left(\xi (x_i, y_i) \frac{df}{dx_i} + \eta (x_i, y_i) \frac{df}{dy_i} \right) \quad . \ . \ . \ . \ (2)$$

The functions of the co-ordinates of n points invariant by Wf will be the 2 n — 1 independent solutions of Wf = 0. n of these solutions may be selected in the form ϕ (x_i, y_i), where ϕ (x, y) is a solution of X f = 0; the remaining n-1 solutions will in general differ from ϕ (x, y) in form.†

r infinitesimal transformations X_1f, X_2f .... X_rf are called *independent* when *no* relation of the form

$$c_1 X_1 f + c_2 X_2 f + \ldots\ldots + c_r X_r f = 0, \ (c_i = \text{const.}),$$

exists. If r independent infinitesimal transformations X_kf, (k = 1...r), be so related as to form a group, then will

$$X_i (X_k f) — X_k (X_i f) \equiv \sum_1^r {}_s \, c_{iks} X_s f, \ (c_{iks} = \text{constants}) \quad . \ . \ . \ (3)$$

* Throughout this paper $\frac{df}{dx}, \frac{df}{dy}$ are employed to denote *partial* differentials of f with respect to x and y.

† Lie: Theorie der Transformationsgruppen, Bd. I., § 59.

The transformations of the *r-parameter* group $X_k f$ may be extended according to the method of (2) above, giving

$$W_k f \equiv \sum_1^n {}_i X_k^{(i)} f, \ (k = 1 \dots r),$$

which determine the increments of a function f $(x_1, y_1; x_2, y_2; \dots x_n, y_n)$. Since the relations (3) exist for $X_i f$, $X_k f$, they must also exist for $W_i f$, $W_k f$, that is

$$W_i(W_k f) - W_k(W_i f) \equiv \sum_1^r {}_s c_{iks} W_s f.$$

Hence, $W_1 f = 0$, $W_2 f = 0$, ... $W_r f = 0$ are known to form a *complete* system of linear partial differential equations in $2n$ variables x_i, y_i, with at least $2n - r$ independent solutions. These $2n - r$ solutions are the invariants of the co-ordinates of n points by the r-parameter group $X_k f$. These solutions we shall call *point-invariants.*

According to the method here outlined we shall determine the *point-invariants* of the finite continuous groups of the plane. In Lie's classification these groups are divided into two classes: (1) Inprimitive, or those groups which leave invariant *one* or *more* families of ∞' curves; (2) Primitive, or those groups leaving invariant *no* family of ∞' curves. Subdivisions of the imprimitive groups will be indicated in the text.

NOTE.—The results of the present paper were worked out early in the spring of 1898. Since that time there has appeared a short article by Dr. Lovette, June number, 1898, of Annals of Mathematics, upon the same subject. Only a few of the *projective* groups are considered, however. Among these are the special linear, and general linear groups.

SECTION I. INVARIANTS OF SUCH IMPRIMITIVE GROUPS AS LEAVE UNCHANGED MORE THAN ONE FAMILY OF ∞' CURVES.

The groups of this category have been reduced by Lie to such canonical forms that they leave invariant:

(A) ∞^∞ of families of ∞' curves: $\phi(x) + \psi(y) = $ constant,

(B) A single infinity of families of ∞' curves: $ax + by = $ constant,

(C) Two families of ∞' curves: $x = $ constant, $y = $ constant.

(A) *The totality of curves* $\phi(x) + \psi(y) = $ constant *remains invariant.*

1. $\boxed{\ q\ }$.*

* Lie employs this symbol to enclose the members of a continuous group;

$$p = \frac{df}{dx}, \quad q = \frac{df}{dy}.$$

This is the only group of the class (A), and furnishes us when *extended* the linear partial differential equation

$$Wf = \sum_1^n i \frac{df}{dy_i} = 0.$$

The invariants of the co-ordinates of n points by this group will be the $2n-1$ independent solutions of $Wf = 0$, *i. e.*

$$x_i,\ \psi_j = y_1 - y_j,\ (i = 1 \ldots\ldots n,\ j = 2 \ldots\ldots n).$$

B. *All families of curves of the form* $ax + by = \text{constant}$ *remain invariant.*

2. $\boxed{p, q}$.

The complete system corresponding to this group is

$$W_1 f \equiv \sum_1^n i \frac{df}{dx_i} = 0, \quad W_2 f \equiv \sum_1^n i \frac{df}{dy_i} = 0,$$

with solutions

$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ (j = 2 \ldots\ldots n).$$

The functions ϕ, ψ are the required invariants.

3. $\boxed{q, xp + yq}$.

From this group we have

$$W_1 f \equiv \sum_1^n i \frac{df}{dy_i} = 0,\ W_2 f \equiv \sum_1^n i \left\{ x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i} \right\} = 0.$$

These two linear partial differential equations evidently have as solutions

$$\zeta_j = \frac{x_j}{x_1},\ u_k = \frac{y_1 - y_k}{y_1 - y_2},\ \sigma = \frac{y_1 - y_2}{x_1},\ (j = 2 \ldots n,\ k = 3 \ldots n),$$

which are the invariants sought.

4. $\boxed{p, q, xp + yx}$.

This three-parameter group furnishes us the complete system

$$\sum_1^n i \frac{df}{dx_i} = \sum_1^n i \frac{df}{dy_i} = \sum_1^n i \left\{ x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i} \right\} = 0.$$

The first two of these equations have solutions

$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ (j = 2 \ldots n),$$

which as new variables reduce the last equation to the form

$$\sum_2^n j \left\{ \phi_j \frac{df}{d\phi_j} + \psi_j \frac{df}{d\psi_j} \right\} = 0.$$

Hence, the invariants are

$$U_k = \frac{\phi_k}{\phi_2} = \frac{x_1 - x_k}{x_1 - x_2},\ V_k = \frac{\psi_k}{\psi_2} = \frac{y_1 - y_k}{y_1 - y_2},\ \sigma = \frac{y_1 - y_2}{x_1 - x_2},\ (k = 3 \ldots n).$$

(C.) *The families of curves* $x = constant$, $y = constant$, *remain invariant.*

5. $\left|\overline{q,\ yq}\right|$.

The complete system corresponding to this group,

$$\sum_1^n i\ \frac{df}{dy_i} = \sum_1^n i\ y_i \frac{df}{dy_i} = 0,$$

has as solutions

x_i, and $\psi_k = (y_1 - y_k) : (y_1 - y_2)$, $(i = 1 \ldots\ldots n,\ k = 3 \ldots\ldots n)$.

Hence. x_i and ψ_k are the invariants.

6. $\left|\overline{q,\ yq,\ y^2q}\right|$.

This is the general projective group in one variable, and leaves invariant x_i and the cross-ratios of any four ordinates.

$$\sum_1^n i\ \frac{df}{dy_i} = \sum_1^n i\ y_i \frac{df}{dy_i} = \sum_1^n i\ y_i^2 \frac{df}{dy_i} = 0.$$

The first two equations of this system have solutions x_i, ψ_k of 5 above. Introducing these solutions as new variables in the last equation, we have

$$\sum_3^n k\ \psi_k\ (\psi_k - 1)\frac{df}{d\psi_k} = 0,$$

whose solutions are

$$x_i,\ \xi_l = \frac{\psi_l - 1}{\psi_l} : \frac{\psi_3 - 1}{\psi_3} = \frac{y_2 - y_l}{y_2 - y_3} : \frac{y_1 - y_l}{y_1 - y_3},\ (l = 4 \ldots\ldots n).$$

7. $\left|\overline{q,\ yq,\ p}\right|$.

This group leaves invariant

$\psi_k = (y_1 - y_k) : (y_1 - y_2)$, and $\phi_j = x_1 - x_j$, $(k = 3 \ldots\ldots n,\ j = 2 \ldots\ldots n)$.

8. $\left|\overline{q,\ yq,\ y^2q,\ p}\right|$.

The invariants of this group are clearly

$$\xi_l = \frac{y_2 - y_l}{y_2 - y_3} : \frac{y_1 - y_l}{y_1 - y_3},\ \text{as in 6, and}$$

$$\phi_j = x_1 - x_j,\ \text{as in 7.}$$

9. $\left|\overline{q,\ p,\ xp + cyq}\right|$.

The solutions $\psi_j = y_1 - y_j$, $\phi_j = x_1 - x_j$ of the first two equations obtained from this group, when introduced in the last one, give

$$\sum_2^n j\ \left\{\phi_j \frac{df}{d\phi_j} + c\,\psi_j \frac{df}{d\psi_j}\right\} = 0.$$

The required invariants of the group may now be chosen as

$$U_k = \frac{x_1 - x_k}{x_1 - x_2},\ V_k = \frac{y_1 - y_k}{y_1 - y_2},\ \sigma = \frac{(x_1 - x_2)^c}{y_1 - y_2},\ (k = 3 \ldots\ldots n).$$

10. $\left|\ \underline{q,\ yq,\ p,\ xp}\ \right|$.

Comparing this group with 7, we have at once the invariants

$$U_k = \frac{x_1 - x_k}{x_1 - x_2},\ V_k = \frac{y_1 - y_k}{y_1 - y_2},\ (k = 3 \ldots n).$$

11. $\left|\ \underline{q,\ yq,\ y^2q,\ p,\ xp}\ \right|$.

By comparison with 8 and 10, it will be seen that this five-parameter group leaves invariant

$$\xi_l = \frac{y_2 - y_l}{y_1 - y_l} : \frac{y_2 - y_3}{y_1 - y_3},\ U_k = \frac{x_1 - x_k}{x_1 - x_2},\ (l = 4 \ldots n,\ k = 3, \ldots n).$$

12. $\left|\ \underline{q,\ yq,\ y^2q,\ p,\ xp,\ x^2p}\ \right|$.

Comparing with 6, it will be seen that this group leaves invariant the cross-ratios of any four abscissas, and ordinates:

$$\xi_l = \frac{y_2 - y_l}{y_2 - y_3} : \frac{y_1 - y_l}{y_1 - y_3},\quad \sigma_l = \frac{x_2 - x_l}{x_2 - x_3} : \frac{x_1 - x_l}{x_1 - x_3},\ (l = 4 \ldots n).$$

13. $\left|\ \underline{p + q,\ xp + yq,\ x^2p + y^2q}\ \right|$.

This group furnishes the complete system

$$\sum_1^n{}_i \left\{\frac{df}{dx_i} + \frac{df}{dy_i}\right\} = \sum_1^n{}_i \left\{x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i}\right\} = \sum_1^n{}_i \left\{x_i^2 \frac{df}{dx_i} + y_i^2 \frac{df}{dy_i}\right\} = 0.$$

Selecting
$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ \sigma = x_1 - y_1$$

as solutions of the first equation, we have the remaining equations in the form

$$W_1 f \equiv \sum_2^n{}_j \left\{\phi_j \frac{df}{d\phi_j} + \psi_j \frac{df}{d\psi_j}\right\} + \sigma \frac{df}{d\sigma} = 0,$$

$$W_2 f \equiv \sum_2^n{}_j \left\{\phi_j^2 \frac{df}{d\phi_j} + \psi_j^2 \frac{df}{d\psi_j}\right\} + \sigma^2 \frac{df}{d\sigma} = 0.$$

Solutions of $W_1 f = 0$ may be taken in the form

$$u_k = \frac{\phi_k}{\phi_2},\ v_k = \frac{\psi_k}{\psi_2},\ \omega_1 = \frac{\phi_2}{\sigma},\ \omega_2 = \frac{\psi_2}{\sigma}.$$

Expressing $W_2 f = 0$ in terms of these new variables,

$$\sum_3^n{}_k \left\{u_k(1 - u_k)\frac{df}{du_k} + v_k(1 - v_k)\frac{df}{dv_k}\right\} + \omega_1(1 - \omega_1)\frac{df}{d\omega_1} + \omega_2(1 - \omega_2)\frac{df}{d\omega_2} = 0.$$

We may choose the solutions of this last equation as the cross-ratios

$$\rho_l = \frac{u_l\,(1-u_3)}{u_3\,(1-u_l)} = \frac{x_2-x_l}{x_2-x_3} : \frac{x_1-x_l}{x_1-x_3},\quad \sigma_l = \frac{v_l\,(1-v_3)}{v_3\,(1-v_l)} = \frac{y_2-y_l}{y_2-y_3} : \frac{y_1-y_l}{y_1-y_3},$$

$$(l = 4, \ldots . n),$$

and the ratios

$$t_1 = \frac{\omega_1\,(1-\omega_2)}{\omega_2\,(1-\omega_1)} = \frac{x_1-x_2}{y_1-y_2} : \frac{y_1-x_2}{x_1-y_2},$$

$$t_2 = \frac{u_3\,(1-v_3)}{v_3\,(1-u_3)} = \frac{x_1-x_3}{x_2-x_3} : \frac{y_1-y_3}{y_2-y_3},$$

$$t_3 = \frac{u_3\,(1-\omega_1)}{\omega_1\,(1-u_3)} = \frac{x_1-x_3}{x_2-x_3} : \frac{x_1-x_2}{y_1-x_2}.$$

SECTION II. INVARIANTS OF SUCH IMPRIMITIVE GROUPS AS LEAVE UNCHANGED ONE FAMILY OF ∞' CURVES.

The remaining groups of the imprimitive type leave invariant one family of ∞' curves, and have been reduced by Lie* to such canonical forms that this invariant family is $x = \text{const.}$

14. $\left|\, \overline{X_1 q,\ X_2 q,\ X_3 q,\ \ldots\ldots X_r q} \,\right|.$

In this group X_k is a function of x alone, and $r > 1$. Each curve of the family $x = \text{const.}$ remains singly invariant.

The complete system of linear partial differential equations

$$W_k f \equiv \sum_1^n {}_i\, X_k(x_i) . \frac{df}{dy_i} = 0,\ (k = 1 \ldots . r),$$

corresponding to this group, has as solutions $x_1, x_2, \ldots x_n$ and $n - r$ other independent functions D_s, $(s = 1, 2 \ldots n - r)$, which we shall define as the $n - r$ determinants of the matrix

$$\left\| \begin{matrix} y_1 & y_2 \cdots\cdots & y_{r+s} \cdots\cdots & y_n \\ X_{1(x_1)} & X_{1(x_2)} & \cdots\cdots\cdots\cdots & \\ \cdots\cdots & \cdots\cdots & \cdots\cdots\cdots\cdots & \\ \cdots\cdots & \cdots\cdots & \cdots\cdots\cdots\cdots & \\ X_{r(x_1)} & X_{r(x_2)} & \cdots\cdots\ \cdots\cdots & \end{matrix} \right\|, \qquad (M_r)$$

$$n \geqq r + 1$$

* Lie; Math. Annalen, Bd. XVI; Contin. Gruppen, Chap. 13.

formed by filling the $(r+1)$-th column successively by the $(r+1)$, the $(r+2)$, ..., the n-th column. The invariants are clearly x_i and D_s, $(i=1 \ldots . n$, $s=1, \ldots . n-r)$.

$$15. \quad \boxed{\begin{array}{c} X_1q, X_2q, X_3q, \ldots . X_{r-1}q, yq \\ r>2 \end{array}}.$$

This group furnishes the complete system

$$W_kf \equiv \sum_1^n i\, X_k(x_i)\cdot\frac{df}{dy_i}=0,\ Yf \equiv \sum_1^n i\, y_i\cdot\frac{df}{dy_i}=0.$$

The solutions of $W_kf=0$ are clearly x_i and the determinants D_s, $(s=0, 1 \ldots n-r)$, of a matrix (M_{r-1}) constructed similar to (M_r) in 14. $Yf=0$ requires the ratios $y_i : y_k$ to appear in the final solutions. Hence, we may write as invariants x_i and

$$\xi_t = D_t : D_o,\ (t=1 \ldots . n-r).$$

$$16. \quad \boxed{\begin{array}{c} e^{a_kx}q,\ xe^{a_kx}q,\ x^2e^{a_kx}q,\ \ldots .\ x^{\zeta_k}e^{a_kx}q,\ p \\ k=1, \ldots . m, \sum_1^m k\, \zeta_k+m=r-1, r>2 \end{array}}.$$

From this group we obtain

$$W_k^{t_k}f \equiv \sum_1^n i\ (x_i)^{t_k}\ e^{a_kx_i}.\ \frac{df}{dy_i}=0,\ \ Xf \equiv \sum_1^n i\ \frac{df}{dx_i}=0,\ (t_k=0, 1, \ldots . \zeta_k).$$

The solutions $\phi_j = x_j - x_1$ of the last equation are also solutions of the system. By dividing the remaining equations, respectively, by $e^{a_kx_1}$, the exponents of e become functions of ϕ_j. The independent determinants D_s, $(s=0, 1 \ldots n-r)$, of the matrix (M_{r-1}), formed as indicated in 15, will be solutions. The invariants are, therefore, ϕ_j and D_s.

$$17. \quad \boxed{\begin{array}{c} e^{a_kx}q,\ xe^{a_kx}q,\ x^2e^{a_kx}q,\ \ldots .\ x^{\zeta_k}e^{a_kx}q,\ yq,\ p \\ k=1 \ldots . m,\ \sum_1^m k\, \zeta_k+m=r-2, r>3 \end{array}}.$$

The complete system given by this group is

$$W_k^{t_k}f \equiv \sum_1^n i\ (x_i)^{t_k}.\ e^{a_kx_i}\cdot\frac{df}{dy_i}=0,\ Yf \equiv \sum_1^n i\ y_i\frac{df}{dy_i}=0,\ Xf \equiv \sum_1^n i\ \frac{df}{dx_i}=0,$$

$$(t_k=0, 1 \ldots . \zeta_k).$$

As in 16, the functions $\phi_j = x_j - x_1$ are solutions of $Xf = 0$ and of the system. If a matrix be constructed as indicated in 14 and 16, from the coefficients of the first $r - 2$ equations, it will be observed that the independent determinants D_s, $(s = -1, 0, 1 \dots n - r)$, will be linear and homogeneous in y_i with coefficients composed of functions of ϕ_j. D_s will then be solutions of all equations except $Yf = 0$, which requires the ratios of y_i to appear. Hence, the invariants may be written

$$\phi_j = x_j - x_1, \ \zeta_t = D_t : D_{-1}, \ (j = 2 \dots n, \ t = 0, 1 \dots n - r).$$

18. $\boxed{q, xq, x^2q, \dots x^{r-3}q, p, xp + cyq \quad r > 3}$.

Here the complete system is

$$W_k f \equiv \sum_1^n {}_i \, x_i^k \frac{df}{dy_i} = 0, \ (k = 0, 1 \dots r - 3), \ Xf \equiv \sum_1^n {}_i \, \frac{df}{dx_i} = 0,$$

$$Yf \equiv \sum_1^n {}_i \left\{ x_i \frac{df}{dx_i} + c y_i \frac{df}{dy_i} \right\} = 0.$$

The solutions of $W_0 f = 0$, $Xf = 0$ are

$$\psi_j = y_1 - y_j, \ \phi_j = x_1 - x_j$$

Yf expressed in terms of ψ, ϕ becomes

$$Y_1 f \equiv \sum_2^n {}_j \left\{ \phi_j \frac{df}{d\phi_1} + c\psi_1 \frac{df}{\phi\psi_j} \right\} = 0,$$

with solutions

$$u_k = \phi_k : \phi_2, \ v_j = \psi_j : (\phi_j)^c, \ (k = 3 \dots n).$$

The functions u_k are solutions of the system. We find on introducing u_k and v_j as new variables in Wf, the partial differential equations

$$W_t' f \equiv \frac{df}{dv_2} - \sum_3^n {}_k \, u_k^{t-c} \cdot \frac{df}{dv_k} = 0, \ (t = 1, 2, \dots r - 3),$$

whose solutions may be expressed as determinants D_s of the matrix.

$$\left\| \begin{array}{llllll} v_2 & v_3 & v_4 \dots\dots & v_{r-3+s} & \dots\dots & v_n \\ 1 & u_3^{1-c} & u_4^{1-c} & \dots\dots & \dots\dots & \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 1 & u_3^{r-3-c} & u_4^{r-3-c} & \dots\dots & \dots\dots & u_n^{r-3-c} \end{array} \right\|.$$

Hence, the point-invariants are

$$u_k = \frac{x_1 - x_k}{x_1 - x_2}, \; D_s, \; (k = 3 \ldots. n, s = 1, \ldots. n - r + 2).$$

19. $\boxed{q, xq, x^2q, \ldots. x^{r-3}q, p, xp + [(r-2)y + x^{r-2}]q \atop r>2}$.

The solutions of the complete system

$$W_kf \equiv \sum_1^n i \; x_i^k \frac{df}{dy_i} = 0, (k = 0, 1 \ldots r - 3), \quad Xf \equiv \sum_1^n i \frac{df}{dx_i} = 0,$$

$$Yf \equiv \sum_1^n i \left\{ x_i \frac{df}{dx_i} + [(r-2) y_i + x_i^{r-2}] \frac{df}{dy_i} \right\} = 0,$$

may be obtained in a manner similar to 18. The solutions ϕ_j, ψ_j of $Xf = 0$, $Wf = 0$, introduced as new variables in Yf, give

$$Y'f \equiv \sum_2^n j \left\{ \phi_j \frac{df}{d\phi_j} + [(r-2)\psi_j + \phi_j^{r-2}]. \frac{df}{d\psi_j} \right\} = 0,$$

with solutions

$$u_k = \phi_k : \phi_2, \; v_j = \log \phi_j - \frac{\psi_j}{\phi_j^{r-2}}, \; (k = 3 \ldots\ldots n, j = 2, \ldots n).$$

Introducing u_k, v_j as new variables in Wf, and reducing, we find

$$W_tf = \frac{df}{dv_2} + \sum_2^n k \; u_k^{(t+2-r)} \cdot \frac{df}{dv_k} = 0, \; (t = 1, \ldots r - 3),$$

whose solutions are u_k and the determinants D_t of a matrix constructed as in 18.

The invariants are, therefore,

$$u_k = \frac{x_1 - x_k}{x_1 - x_2}, \; D_s, \; (k = 3 \ldots n, s = 1, \ldots n - r + 2).$$

20. $\boxed{q, xq, x^2q, \ldots\ldots x^{r-4}q, yq, p, xp \atop r > 3}$.

For this group

$$W_tf \equiv \sum_1^n i \; x_i^t \frac{df}{dy_i} = 0, \; t = 0, 1, \ldots r - 4),$$

$$Yf \equiv \sum_1^n i \; y_i \frac{df}{dy_i} = 0, \quad X_1f \equiv \sum_1^n i \frac{df}{dx_i} = 0, \quad X_2f \equiv \sum_1^n i \; x_i \frac{df}{dx_i} = 0.$$

The last two equations show that the ratios of the differences of the x's, say

$$u_k = \frac{x_1 - x_k}{x_1 - x_2}, \; (k = 3, \ldots. n),$$

shall appear in the final solutions. The $n - r + 3$ independent determinants D_s, $(s = 0, 1 \ldots . n - r + 2)$, of the matrix

$$\begin{vmatrix} y_1 & y_2 & y_3 & \cdots\cdots & y_{r-2+s} & \cdots & y_n \\ 1 & 1 & 1 & \cdots\cdots & 1 & \cdots\cdots & 1 \\ x_1 & x_2 & x_3 & \cdots\cdots & x_{r-2+s} & \cdots & x_n \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_1^{r-4} & x_2^{r-4} & x_3^{r-4} & \cdots & x_{r-2+s}^{r-4} & \cdots & x_n^{r-4} \end{vmatrix},$$

are solutions of the first $r - 3$ equations $W_k f = 0$. These determinants are, at the same time, homogeneous in y_i and in $x_i - x_k$; their ratios will, therefore, satisfy the requirements of u_k and $Yf = 0$. Hence, we may write our $2n - r$ invariants as $u_k = (x_1 - x_k) : (x_1 - x_2)$ and $R_t = D_t : D_0$, $(k = 3 \ldots n, t = 1 \ldots n - r + 2)$.

21. $\boxed{q, xq, x^2q, \ldots . x^{r-4}q, p, 2xp + (r-4)yq, x^2p + (r-4)xyq \quad r>4}$.

From this group we obtain the differential equations

$$W_t f \equiv \sum_1^n i\, x_i^t \frac{df}{dy_i} = 0, (t = 0, 1 \ldots r-4), \; Xf \equiv \sum_1^n i \frac{df}{dx_i} = 0,$$

$$X_1 f \equiv \sum_1^n i \left\{ 2x_i \frac{df}{dx_i} + (r-4)\, y_i \frac{df}{dy_i} \right\} = 0,$$

$$X_2 f \equiv \sum_1^n i \left\{ x_i^2 \frac{df}{dx_i} + (r-4)\, x_i y_i \frac{df}{dy_i} \right\} = 0.$$

The solutions of $W_0 f = 0$, $Xf = 0$ are $\psi_j = y_1 - y_j$, $\phi_j = x_1 - x_j$, respectively. $X_2 f$ when expressed in these new variables becomes

$$X_2' f \equiv \sum_2^n j \left\{ \phi_j^2 \frac{df}{d\phi_j} + (r-4)\, \phi_j \psi_j \frac{df}{d\psi_j} \right\} = 0,$$

whose solutions may be selected in the forms

$$u_k = \frac{1}{\phi_2} - \frac{1}{\phi_k}, \; v_j = \frac{\psi_j}{\phi_j^{r-4}}, \; (k = 3 \ldots . n, j = 2 \ldots . n).$$

$$X_1' f \equiv 2 \sum_3^n k\, u_k \frac{df}{du_k} + (r-4) \sum_2^n j\, v_j \frac{df}{dv_j} = 0$$

has solutions

$\sigma_l = u_l : u_3$, $\zeta_k = v_k : u_k^{\frac{1}{2}(r-4)}$, $\zeta_2 = v_2 : u_3^{\frac{1}{2}(r-4)}$, $(k = 3 \ldots . n, l = 4 \ldots . n)$.

The remaining equations W f may be expressed in terms of σ, ζ in the following forms:

$$\frac{df}{d\zeta_2}+\frac{df}{d\zeta_3}+\sum_4^n l\ (\sigma_l)^{-d}.\ \frac{df}{d\zeta_l}=0,\ [d=\tfrac{1}{2}(r-4)],$$

$$W_t'f\equiv\frac{df}{d\zeta_3}+\sum_4^n l\ (\sigma)^{t-d}.\ \frac{df}{d\zeta_l}=0,\ (t=1,\ \ldots.\ r-5).$$

The solutions of these equations may be expressed as the determinants D_s, $(s=1,\ \ldots.\ n-r+3)$, of the matrix

$$\left\|\begin{array}{ccccccc} \zeta_2 & \zeta_3 & \zeta_4 & \ldots. & \zeta_{r-3+s} & \ldots. & \zeta_n \\ 1 & 1 & \sigma_4^{-d} & \ldots. & \sigma_{r-3+s}^{-d} & \ldots. & \sigma_n^{-d} \\ 0 & 1 & \sigma_4^{1-d} & \ldots. & \ldots\ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 1 & \sigma_4^{r-5-d} & & \ldots\ldots & \ldots & \ldots \end{array}\right\|.$$

The required invariants are, therefore,

$$\sigma_l=\frac{x_2-x_l}{x_1-x_l}:\frac{x_2-x_3}{x_1-x_3},\ D_s,\ (l=4\ \ldots.\ n,\ s=1,\ \ldots.\ n-r+3).$$

22. $\boxed{q,\ xq,\ x^2q,\ \ldots\ldots\ x^{r-5}q,\ yq,\ p,\ xp,\ x^2p+(r-5)\,xyq \quad r>5}$.

This group furnishes the system

$$W_tf\equiv\sum_1^n i\ x_i^t\ \frac{df}{dy_i}=0,\ (t=0,\ 1\ \ldots.\ r-5),\quad Yf\equiv\sum_1^n i\ y_i\ \frac{df}{dy_i}=0,$$

$$Xf\equiv\sum_1^n i\ \frac{df}{dx_i}=0,\quad X_1f\equiv\sum_1^n i\ x_i\ \frac{df}{dx_i}=0,$$

$$X_2f\equiv\sum_1^n i\ \left\{x_i^2\ \frac{df}{dx_i}+(r-5)\ x_iy_i\ \frac{df}{dy_i}\right\}=0.$$

The solutions of $W_0f=0$ are $\psi_j=y_1-y_j$, those of $X_1f=0$, $Xf=0$ are $u_k=(x_1-x_k):(x_1-x_2)$. X_2f expressed in ψ, u is

$$X_2^1f\equiv\sum_3^n k\ \left\{u_k\,(u_k-1)\ \frac{df}{du_k}+(r-5)\ u_k.\ \frac{df}{d\psi_k}\right\}+(r-5)\ \psi_2\,\frac{df}{d\psi_2}=0,$$

whose solutions are

$$\sigma_l=\frac{u_3\,(u_l-1)}{u_l\,(u_3-1)},\ \zeta_k=\frac{\psi_k}{(u_k-1)^{r-5}},\ \zeta_2=$$
$$\psi_2\left(\frac{u_3}{u_3-1}\right)^{r-5},\quad (l=4\ \ldots\ n,\ k=3\ \ldots\ n).$$

The remaining equations expressed in these new variables are

$$\left.\begin{aligned} &\frac{df}{d\zeta_2}+\frac{df}{d\zeta_3}+\sum_4^n l\,(\sigma_l)^{5-r}.\,\frac{df}{d\zeta_l}=0,\\ &W_t^1 f\equiv\frac{df}{d\zeta_3}+\sum_4^n l\,(\sigma_l)^{-t}.\,\frac{df}{d\zeta_l}=0,\ (t=1\ \ldots.\ r-5),\end{aligned}\right\}\ (1)$$

$$Y^1 f\equiv\sum_2^n j\ \zeta_j.\ \frac{df}{d\zeta_j}=0.$$

The determinants D_s ($s=0, 1 \ldots. n-r+3$), of the matrix formed from equations (1) as in 21 will be solutions of (1). D_s will be linear in ζ, but $Y^1f=0$ requires the ratios of ζ's. We may write our invariants as

$$\sigma_l=\frac{x_2-x_l}{x_1-x_l}:\frac{x_2-x_3}{x_1-x_3},\ R_t=D_t:D_0,\ (l=4\ \ldots.\ n,\ t=1\ \ldots.\ n-r+3).$$

23. $\boxed{p,\ 2xp+yq,\ x^2p+xyq.}$.

This projective group, leaving invariant the x-axis, furnishes us the complete system

$$\sum_1^n i\ \frac{df}{dx_i}=\sum_1^n i\ \left\{2x_i\,\frac{df}{dx_i}+y_i\,\frac{df}{dy_i}\right\}=\sum_1^n i\ \left\{x_i^2\,\frac{df}{dx_i}+x_iy_i\,\frac{df}{dy_i}\right\}=0.$$

The first of these equations has solutions y_i and $\phi_j=x_1-x_j$. The last equation then becomes

$$\sum_2^n j\ \left\{\phi_j^2\,\frac{df}{d\phi_j}+y_j\phi_j\,\frac{df}{dy_j}\right\}=0,$$

with solutions

$$u_k=\frac{1}{\phi_2}-\frac{1}{\phi_k},\ v_j=\frac{\phi_j}{y_j},\ y_1.$$

The second equation is now

$$y_1\,\frac{df}{dy_1}+\sum_2^n j\ \ v_j\,\frac{df}{dv_j}-2\sum_3^n k\ \ u_k\,\frac{df}{du_k}=0,$$

whose solutions we may choose in the forms

$$\delta_l=\frac{u_l}{u_3},\ \zeta_k=\frac{v_k}{v_2},\ \zeta_2=\frac{v_2}{y_1},\ \zeta_1=y_1v_2u_3,\ (l=4\ \ldots.\ n,\ k=3\ \ldots.\ n).$$

Our invariants are

$$\delta_l=\frac{x_2-x_l}{x_2-x_3}:\frac{x_1-x_l}{x_1-x_3},\ \zeta_k=\frac{x_1-x_k}{x_1-x_2}:\frac{y_k}{y_2},\ \zeta_2=\frac{{}_1x-x_2}{y_1y_2},\ \zeta_1=\frac{x_2-x_3}{x_1-x_3}:\frac{y_2}{y_1},$$

whose geometric significance is apparent.

24. $\boxed{yq,\ p,\ xp,\ x^2p+nyq}$.

This four-parameter projective group yields the complete system

$$\sum_1^n i \; y_i \frac{df}{dy_i} = \sum_1^n i \; \frac{df}{dx_i} = \sum_1^n i \; x_i \frac{df}{dx_i} = \sum_1^n i \left\{ x_i^2 \frac{df}{dx_i} + x_i y_i \frac{df}{dy_i} \right\} = 0.$$

Here, we introduce the solutions

$$\phi_j = x_1 - x_j, \; \psi_j = \frac{y_j}{y_1},$$

of the first two equations in the last two, and have

$$\sum_2^n j \; \phi_j \frac{df}{\sigma\phi_j} = \sum_2^n j \left\{ \phi_j^2 \frac{df}{\sigma\phi_j} + \phi_j \psi_j \frac{df}{\varphi\psi_j} \right\} = 0.$$

The last of these new equations is satisfied by

$$u_k = \frac{1}{\varphi_1} - \frac{1}{\phi_k}, \; v_j = \frac{\phi_j}{\psi_j}, \; (k = 3 \ldots . n, \; j = 2 \ldots . n);$$

the first now becomes

$$\sum_3^n k \; u_k \frac{df}{du_k} - \sum_2^n j \; v_j \frac{df}{dv_j} = 0.$$

The solutions of this equation are the requred invariants:

$$\sigma_l = \frac{u_l}{u_3} = \frac{x_2 - x_l}{x_2 - x_3} : \frac{x_1 - x_l}{x_1 - x_3}, \; (l = 4 \ldots . n),$$

$$\zeta_k = \frac{v_k}{v_2} = \frac{x_1 - x_k}{x_1 - x_2} : \frac{y_k}{y_2}, \; (k = 3 \ldots . n),$$

$$\omega = u_3 v_2 = \frac{x_2 - x_3}{x_1 - x_3} : \frac{y_2}{y_1}.$$

SECTION III. INVARIANTS OF THE PRIMITIVE GROUPS.

The remaining finite continuous groups of the plane leave *no* family of ∞' curves invariant, and may be reduced by a proper choice of variables to some one of the canonical forms known as (1) special linear, (2) general linear, (3) general projective.*

25. *The special linear group*

$$\left| \; \overline{p, \; q, \; xq, \; xp - yq, \; yp} \; \right| .$$

The invariant functions of the coördinates of *n* points will be the $2n-5$ independent solutions of the complete system

$$\sum_1^n j \; \frac{df}{dx_i} = \sum_1^n i \; \frac{df}{dy_i} = \sum_1^n i \; x_i \frac{df}{dy_i} = \sum_1^n i \left\{ x_i \frac{df}{dx_i} - y_i \frac{df}{dy_i} \right\} = \sum_1^n i \; y_i \frac{df}{dx_i} = 0. \quad (1)$$

*Lie: Math. Annalen, Bd. XVI, p. p. 518–522, also Contin. Gruppen, p. 351.

The first two equations show the solutions of the system to be functions of

$$\phi_j = x_1 - x_j,\ \psi_j = y_1 - y_j,\ (j = 2 \ldots . n).$$

The remaining equations then take the forms

$$\sum_2^n j\ \phi_j \frac{df}{d\psi_j} = \sum_2^n j \left\{ \phi_j \frac{df}{d\phi_j} - \psi \frac{df}{d\psi_j} \right\} = \sum_2^n j\ \psi_j \frac{df}{d\phi_j} = 0. \quad \ldots\ldots\ldots (2)$$

The second of these equations has solutions

$$u_j = \phi_j\, \psi_j,\ v_k = \phi_2\, \psi_k,\ (k = 3 \ldots . n).$$

With u and v as new variables, the first and third of equations (2) become

$$\frac{df}{du_2} + \sum_3^n k \left\{ \frac{u_k^2}{v_k^2} \frac{df}{du_k} + \frac{u_k}{v_k} \frac{df}{dv_k} \right\} = 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$u_2 \frac{df}{du_2} + \frac{1}{u_2} \sum_3^n k\ v_k^2 \frac{df}{u_k} + \frac{1}{v_3} \sum_3^n k\ v_k \frac{df}{dv_k} = 0. \quad \ldots\ldots (4)$$

The solutions of (3) are found to be

$$\sigma_k = \frac{v_k}{u_k},\ \zeta_k = u_2 - \frac{v_k^2}{u_k}.$$

Equation (4) then reduces to

$$\sum_3^n k \left\{ \sigma_k \zeta_k \frac{df}{d\sigma_k} + \zeta_k^2 \frac{df}{d\zeta_k} \right\} = 0,$$

whose solutions may be written

$$I'_k = \frac{\zeta_k}{\sigma_k},\ J_l = \frac{1}{\zeta_l} - \frac{1}{\zeta_3},\ (k = \ldots . n, l = 4 \ldots . n).$$

Since any functions of I′, J will be the solutions of (1), we may choose

$$I'_k = \frac{\zeta_k}{\sigma_k} = \left| 1\ 2\ k \right| \text{ and } D_l = J_l\, I_3'\, I_l' = \left| 1\ 3\ l \right|,$$

$$\text{where } |\, i\, j\, k\, | = \begin{vmatrix} x_i & y_i & 1 \\ x_j & y_j & 1 \\ x_k & y_k & 1 \end{vmatrix},$$

as solutions, and, therefore, as the $2n - 5$ invariants of the group.

The forms of I′ and D show that *the special linear group leaves invariant all areas.*

26. *The general linear group*

$$\left| \overline{p,\ q,\ xq,\ xp - yq,\ yp,\ xp + yq} \right|.$$

This group furnishes a complete system of six linear partial differential equations, the first five of which are identical with equations (1) of the preceding section. Hence we need only determine the functions of I′ and D which satisfy

$$\sum_1^n i \left\{ x_i \frac{df}{dx_i} + y_i \frac{df}{dy_i} \right\} = 0.$$

This equation requires x, y to enter in the final solutions to the degree zero. Hence, we may write at once the invariants in the form

$$I_l = \frac{I_l'}{I_3'} = |\ 1\,2\,l\ | : |\ 1\,2\,3\ |,$$

$$J_l = \frac{D_l}{I_3} = |\ 1\,3\,l\ | : |\ 1\,2\,3\ |, \ (l = 4 \ldots\ldots n).$$

I and J show that by *the general linear group the ratio of areas remains constant.*

27. *The general proejctive group*

$$\left|\overline{p,\ q,\ xq,\ xp - yq,\ yp,\ xp + yq,\ x^2p + xyq,\ xyp + y^2q}\right|.$$

The members of this group extended and equated to zero furnish a complete system of eight linear partial differential equations, the first six of which are identical with those of the general linear group, and therefore have solutions I, J, defined in 26. The last two equations,

$$\sum_1^n i \left\{ x_i^2 \frac{df}{dx_i} + x_i y_i \frac{df}{dy_i} \right\} = \sum_1^n i \left\{ x_i y_i \frac{df}{dx_i} + y_i^2 \frac{df}{dy_i} \right\} = 0,$$

when expressed in terms of I, J, become somewhat complex, viz.:

$$(1)\quad J_4 (I_4 - J_4 - 1) \frac{df}{dJ_4} + \sum_5^n m \left\{ I_m (I_4 J_m - I_m J_4 - J_m + J_4) \frac{df}{dI_m} + \right.$$

$$\left. J_m (I_4 J_m - I_m J_4 - J_m + I_4 - 1) \frac{df}{dJ_m} \right\} = 0.$$

$$(2)\quad I_4 \ (J_4 - I_4 + 1) \frac{df}{dI_4} + \sum_5^n m \left\{ J_m (I_4 J_m - I_m J_4 - I_m + I_4) \frac{df}{dJ_m} + \right.$$

$$\left. I_m (I_4 J_m - I_m J_4 - I_m + J_4 + 1) \frac{df}{dI_m} \right\} = 0.$$

After considerable manipulation, the solutions of (1) are found to be

$$I_4,\ \phi_m = \frac{I_m J_4}{J_m},\ \psi_m = \frac{\phi_m + I_m (I_4 - \phi_m - 1)}{I_m (J_4 - I_4 + 1)},\ \ (m = 5 \ldots\ldots n)\ .$$

With I_4, ϕ_m, ψ_m as new variables, equation (2) becomes

$$I_4 \frac{df}{dI_4} + \sum_5^n m\ \phi_m \frac{df}{d\phi_m} = 0,$$

with solutions

$$Q_m = \frac{\phi_m}{I_4},\ \ \psi_m\ .$$

Selecting as invariants Q_m and $H_m = \frac{1+\psi_m}{Q_m}$, and restoring the variables $x_i\, y_i$, we have

$$Q_m = \frac{|\,1\,2\,m\,|}{|\,1\,2\,4\,|} : \frac{|\,1\,3\,m\,|}{|\,1\,3\,4\,|}, \quad H_m = \frac{|\,1\,2\,4\,|}{|\,1\,2\,m\,|} : \frac{|\,2\,3\,4\,|}{|\,2\,3\,m\,|}\,.$$

The forms of Q and H show that *the general projective group leaves invariant the cross-ratios of five points.*

Differential Invariants Derived from Point-Invariants.

By David A. Rothrock.

In an accompanying article concerning Point-Invariants, the writer has shown how a group

$$X_k f \equiv \xi_k(x, y)\frac{df}{dx} + \eta_k(x, y)\frac{df}{dy}, \quad (k = 1 \,\ldots\, r),$$

may be *extended* to include the increments of the coördinates of *n* points. The members of a group may be *extended* in a different manner, and indeed so as to include the increments of

$$\frac{dy}{dx},\ \frac{d^2y}{dx^2},\ \frac{d^3y}{dx^3},\ \ldots\,.$$

For example, the group $X_k f$ gives to x and y the increments

$$\delta x = \xi_k \delta t,\ \delta y = \eta_k \delta t,$$

and to $y' = \frac{dy}{dx}$, the increment

$$\delta y' = \frac{dx\,.\,\delta dy - dy\,.\,\delta dx}{dx^2} = \frac{d\eta_k - y' d\xi_k}{dx}\delta t \equiv \eta'_k \delta t.$$

Similarly, $y'' = \frac{d^2y}{dx^2}$ receives the increment

$$\delta y'' = \frac{d\eta'_k - y'' d\xi_k}{dx}\,\delta t \equiv \eta''_k \delta t,$$

and in general

$$\delta y^{(m)} = \frac{d\eta_k{}^{(m-1)} - y^m d\xi_k}{dx}\,\delta t \equiv \eta_k{}^{(m)} \delta t.$$

The group $X_k f$ so extended becomes

$$X_k^{(m)} f \equiv \zeta_k \frac{df}{dx} + \eta_k \frac{df}{dy} + \eta_k^{(1)} \frac{df}{dy^1} + \eta_k^{(2)} \frac{df}{dy^{(2)}} + \dots + \eta_k^{(m)} \frac{df}{dy^{(m)}} .^*$$

Lie has shown that the extended transformations $X_k^{(m)} f$ form an r — parameter group since the *bracket relations*

$$(X_i^{(m)}, X_k^{(m)}) \equiv X_i^{(m)} (X_k^{(m)} f) - X_k^{(m)} (X_i^{(m)} f) \equiv \sum_1^r {}_s\, c_{iks}\, X_s^{(m)} f \dots\dots\dots\dots (1)$$

exist. But when relations (1) hold, the equations

$$X_k^{(m)} f \equiv \xi_k \frac{df}{dx} + \eta_k \frac{df}{dy} + \sum_1^m {}_i\, \eta_k^{(i)} \frac{df}{dy^{(i)}} = 0$$

are known to form a complete system of linear partial differential equations in $2 + m$ variables. This system has at least $2 + m - r$ independent solutions which are defined as the *differential invariants* of the group $X_k f$.

In Lie's paper cited above it is shown that if two independent differential invariants be known, all others may be found by differentiation. For example, if the two fundamental differential invariants be ϕ_1, ϕ_2, then

$$\phi_3 = \frac{d\varphi_2}{d\varphi_1},\ \phi_4 = \frac{d\phi_3}{d\phi_1}, \dots\dots$$

The fundamental differential invariants $\varphi_1 (x, y, y_1, y_2, \dots y_{r-1})$, $\varphi_2 (x, y, y_1, y_2, \dots y_r)$, of an r-parameter group may, in general, be obtained from a somewhat different point of view, and indeed without a knowledge of the form of the group itself, provided the point-invariants of the group be known.

Let us suppose the points of a point-invariant $\Theta (x, y, x^{(2)}, y^{(2)} \dots)$ to lie upon a curve $x = f_1 (t)$, $y = f_2 (t)$,
where f_1, f_2 are analytic functions of the parameter t. We seek the nature of the invariants when two or more points upon this curve approach coincidence. If x, y be a point for $t = t_0$, then a point $x^{(2)}$, $y^{(2)}$, ultimately coincident with x, y, will be given by

$$x^{(2)} = x + x' dt + x'' \frac{dt^2}{2} + \dots,\ y^{(2)} = y + y'dt + y'' \frac{dt^2}{2} = \dots, \quad \dagger$$

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* Lie: Ueber Differentialgleichungen, die eine Gruppe gestatten. Mathematische Annalen, Bd. XXXII.

†Throughout this paper we shall employ the following notation:

(a) x, y; $x^{(2)}, y^{(2)}$; $x^{(3)}, y^{(3)}$; .... are points of the plane.

(b) $x' = \frac{dx}{dt},\ x'' = \frac{d^2x}{dt^2}, \dots;\ y' = \frac{dy}{dt},\ y'' = \frac{d^2y}{dt^2}, \dots$.

(c) $y_1 = \frac{dy}{dx},\ y_2 = \frac{d^2y}{dx^2}, \dots$; hence, we have $y' = y_1 x'$,

$y'' = y_2 (x')^2 + y_1 x''$, $y''' = y_3 (x')^3 + 3y_2 x' x'' + y_1 x'''$, ...

and similarly with other parameters for any number of consecutive points. On substituting these series expansions of $x^{(i)}$, $y^{(i)}$ in Θ, we shall evidently obtain an invariant function. If now Θ be capable of expansion in a power-series with regard to dt, dr, ..., we shall have the coefficients, I_1 $(x, y, x', y', \ldots)$, I_2 $(x_1 y, x', y', \ldots)$, ..., of the powers of dt, dr, ... separately invariant, since the parameters t, r, ... are arbitrary. In I_1, I_2, I_3 .... we may express $y', y'', y''', \ldots$ as functions of $y_1, y_2, \ldots\ x', x'', x''', \ldots\ldots$ If then $I_1, I_2, I_3, \ldots$ may be so combined as to eliminate the differentials $x', x'', x''', \ldots$, we shall obtain invariant functions, ϕ_1 $(x, y, y_1, y_2, \ldots\ldots)$, ϕ_2, ϕ_3, ..., which are *differential invariants* in the sense already defined.

The calculation of differential invariants by the method just outlined is sometimes quite laborious. Below is given a consideration of some of the more characteristic groups.

SECTION I. DIFFERENTIAL INVARIANTS DETERMINED BY TWO POINTS.

In the present section are computed the differential invariants for some of the more simple groups of the plane, and indeed for such as have point-invariants for two distinct points. Only two differential invariants have been determined for each group; all others may be found from these by differentiation.*

1. The group

$$\boxed{q}$$

has the point-invariants $x^{(i)}$, $\psi_2 = y - y^{(2)}$. Expressing $y^{(2)}$ in terms of a parameter t, we have ultimately

$$\psi_2 = y - (y + y'dt + y''\frac{dt^2}{2} + \ldots.).$$

Since dt is arbitrary, y', y'', ... are singly invariant.

$y' = x'y_1$, but x' as well as x is invariant, hence y_1 is invariant, and our differential invariants may be written

$$\phi_1 = x, \phi_2 = y_1 \cdot$$

2. The group

$$\boxed{p, q}$$

has the point-invariants

$$u_2 = x - x^{(2)},\ v_2 = y - y^{(2)}.$$

Hence, we have

$$u_2 = x - (x + x'dt + x''\frac{dt^2}{2} + \ldots),\quad v_2 = y - (y + y'dt + y''\frac{dt^2}{2} + \ldots),$$

*Lie: Math. Annalen, Bd. XXXII, p. 220.

which show $x', x'', \ldots\ldots, y', y'', \ldots\ldots$ to be invariant. But $y' = y_1 x'$, $y'' = y_2(x')^2 + y_1 x''$; hence, y_1, y_2 must each be invariant.

$$\therefore \phi_1 = y_1, \ \phi_2 = y_2 .$$

3. The point-invariants of the group

$$\boxed{q, \ xp + yq}$$

are

$$u_2 = \frac{x^{(2)}}{x}, \ v_2 = \frac{y - y^{(2)}}{x} .$$

Introducing the series expansion of $x^{(2)}$, $y^{(2)}$,

$$u_2 = \left(x + x'dt + x''\frac{dt^2}{2} + \ldots\right) : x,$$

$$v_2 = \left\{y - \left(y + y'dt + y''\frac{dt^2}{2} + \ldots\right)\right\} : x .$$

u_2 shows the ratios

$$\frac{x'}{x}, \frac{x''}{x}, \frac{x'''}{x}, \ldots\ldots \tag{1}$$

to be invariant, while v_2 requires the invariance of

$$\frac{y'}{x}, \frac{y''}{x}, \frac{y'''}{x}, \ldots\ldots$$

$$I_1 = \frac{y'}{x} = \frac{y_1 x'}{x};$$

hence y_1 is invariant on account of (1).

$$I_2 = \frac{y''}{x} = \frac{y_2(x')^2 + y_1 x''}{x}, \text{ or } I_2 - \phi_1 \frac{x''}{x} = xy_2\left(\frac{x'}{x}\right)^2 .$$

Therefore, $\phi_1 = y_1$, $\phi_2 = xy_2$.

4. The group

$$\boxed{p, \ q, \ xp + yq}$$

has the point-invariants

$$u_2 = \frac{y - y^{(2)}}{x - x^{(2)}}, \ v_3 = \frac{x - x^{(3)}}{x - x^{(2)}} .$$

One differential invariant may be computed from u_2 alone, but a second can not be had on account of impossibility of the elimination of the parameters. We therefore consider three points determined by t, r.

$$u_2 = \left\{y - \left(y + y'dt + y''\frac{dt^2}{2} + \ldots\right)\right\} : \left\{x - \left(x + x'dt + x''\frac{dt^2}{2} + \ldots\right)\right\}$$

$$= \frac{y'}{x'} + \frac{dt}{2}\left(\frac{y''}{x'} - \frac{y'x''}{(x')^2}\right) + \frac{dt^2}{2}\left(\frac{y'(x'')^2}{2(x')^3} - \frac{y'x'''}{3(x')^2} - \frac{y''x''}{2(x')^2} + \frac{y''}{3x'}\right) + \ldots,$$

$$v_3 = \left\{x - (x + x'\,dr + x''\frac{dr^2}{2} + \ldots .)\right\} : \left\{x - x\,(+ x'\,dt + x''\frac{dt^2}{2} + \ldots .\right\}$$

$$= \frac{dr}{dt} - \frac{dr}{2} \cdot \frac{x''}{x'} - \frac{dr^2}{4}\left(\frac{x''}{x'}\right)^2 + dt\,dr\left\{\left(\frac{x''}{2x'}\right)^2 - \frac{x'''}{6x'}\right\} + \ldots\ldots .$$

These functions show

$$\frac{x''}{x'},\ I_1 = \frac{y'}{x'} = y_1,\ I_2 = \frac{y''}{x'} - \frac{y'x''}{(x')^2} = y_2\,x', \text{ and}$$

$$I_3 = \frac{y'''}{3\,x'} - \frac{y''\,x''}{2\,(x')^2} - \frac{y'\,x'''}{3\,(x')^2} + \frac{y'\,(x'')^2}{2\,(x')^3} = \frac{y_3\,(x')^3}{3} + \frac{y_2 x''}{2}$$

to be invariant. Eliminating the parameters x', x'', we have

$$\left\{I_3 \div I_2 - \frac{x''}{2x'}\right\} \div I_2 = \frac{y_3}{3\,(y_2)^2}.$$

$$\therefore \phi_1 = y_1,\ \phi_2 = \frac{y_3}{{y_2}^2}.$$

SECTION II. DIFFERENTIAL INVARIANTS DETERMINED BY THREE OR MORE POINTS.

In the case of the more complex groups it is necessary to bring into consideration three, four, five, ... points, and consequently employ additional parameters, r, s, ...

5. For three points, the group

$$\boxed{p,\ q,\ xp + cyq}$$

possesses the point-invariants

$$u = \frac{y - y^{(2)}}{(x - x^{(2)})^c},\quad v_3 = \frac{x - x^{(3)}}{x - x^{(2)}},\quad w_3 = \frac{y - y^{(3)}}{y - y^{(2)}}\ .$$

Expressing u, in series expansion for $x^{(2)}$, $y^{(2)}$, we have

$$u = \frac{y - (y + y'dt + y''\frac{dt^2}{2} + .)}{\left\{x - (x + x'dt + x''\frac{dt^2}{2} + ..)\right\}^c}$$

$$= \frac{k}{(x')^c}\left\{y' + \frac{dt}{2}\left[y'' - cy'\frac{x''}{x'}\right] + \right.$$

$$\left. dt^2\left[\frac{y'''}{6} - \frac{cy''}{4}\cdot\frac{x''}{x'} + y'\left(l\left(\frac{x''}{x'}\right)^2 - \frac{c}{6}\,\frac{x'''}{x'}\right)\right]\ldots .\right\}.$$

The series expansion of v_3 is identical with that of v_3 in 4 above. Hence, the invariant functions may be written

$$\frac{x''}{x'}, \frac{x'''}{x'}, \frac{x^{iv}}{x'}, \ldots, I_1 = \frac{y'}{(x')^c} = \frac{y_1}{(x')^{c-1}}, I_2 = \frac{y''}{(x')^c} - cy' \frac{x''}{(x')^{c+1}} =$$

$$\frac{y_2}{(x')^{c-2}} + h \cdot I_1 \frac{x''}{x'},$$

$$I_3 = \frac{y'''}{6(x')^c} - \frac{cy''}{4(x')^c} \cdot \frac{x''}{x'} + \frac{y'}{(x')^c} \left\{ l \left(\frac{x''}{x'}\right)^2 - \frac{c}{6} \cdot \frac{x'''}{x'} \right\}$$

$$= k_1 \frac{y_3}{(x')^{c-3}} + k_2 \frac{x''}{x'} \cdot \frac{y_2}{(x')^{c-2}} + \left\{ k_3 \frac{x'''}{x'} + k_4 \left(\frac{x''}{x'}\right)^2 \right\} \frac{y_1}{(x')^{c-1}}$$

From these relations follows at once the invariance of

$$\frac{y_1}{(x')^{c-1}}, \frac{y_2}{(x')^{c-2}}, \frac{y_3}{(x')^{c-3}}.$$

By eliminating x', we have

$$\phi_1 = \frac{y_2}{y_1^{\frac{c-2}{c-1}}}, \quad \phi_2 = \frac{y_3}{y_1^{\frac{c-3}{c-1}}}.$$

6. $\boxed{q, yq}$ leaves invariant x and $v_3 = \dfrac{y - y^{(3)}}{y - y^{(2)}}$. Expanding v_3 in series,

$$v_3 = \left\{ y - (y + y' dr + y'' \frac{dr^2}{2} \ldots) \right\} : \left\{ y - (y + y' dt + y'' \frac{dt^2}{2} + \ldots) \right\}$$

$$= \frac{dr}{dt} - \frac{dr}{2} \frac{y''}{y'} - dr^2 \left(\frac{y''}{2y'}\right)^2 + \ldots,$$

which gives invariant functions $\dfrac{y''}{y'}, \dfrac{y'''}{y'}, \ldots$. The functions $x, x', x'' \ldots$ are also invariant.

$$I_1 = \frac{y''}{y'} = \frac{y_2}{y_1} x' + \frac{x''}{x'}.$$

$$\therefore \phi_1 = x, \ \phi_2 = \frac{y_2}{y_1}.$$

7. The group

$$\boxed{q, yq, p}$$

has point-invariants

$$u_2 = x - x^{(2)}, \ v_3 = \frac{y - y^{(3)}}{y - y^{(2)}}.$$

We have, as in 6, the invariant functions

$$x',\ x'',\ x''',\ \ldots,\ I_1 = \frac{y''}{y'} = \frac{y_2 x'}{y_1} + \frac{x''}{x'},$$

$$I_2 = \frac{y'''}{y'} = \frac{y_3 (x')^2}{y_1} + 3\,\frac{y_2 x''}{y'} + \frac{x'''}{x'}.$$

$$\therefore \phi_1 = \frac{y_2}{y_1},\quad \phi_2 = \frac{y_3}{y_1}.$$

8. The point-invariants of the four-parameter group

$$\boxed{p,\ xp,\ q,\ yq}$$

are
$$u_3 = \frac{x - x^{(3)}}{x - x^{(2)}},\quad v_3 = \frac{y - y^{(3)}}{y - y^{(2)}}.$$

The series expansion for u_3, v_3 in powers of dt, dr will be identical with those for v_3 in 4 and 7, respectively. Hence, we have the invariant differential functions

$$\frac{x''}{x'},\ \frac{x'''}{x'},\ \frac{x^{iv}}{x'},\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1),$$

and

$$I_1 = \frac{y''}{y'} = \frac{y_2 x'}{y_1} + \frac{x''}{x'},\ I_2 = \frac{y'''}{y'} = \frac{y_3 (x')^2}{y_1} + 3\frac{y_2 x'}{y_1}\cdot\frac{x''}{x'} + \frac{x'''}{x'},$$

$$I_3 = \frac{y^{iv}}{y'} = \frac{y_4 (x')^3}{y_1} + \frac{6\, y_3 (x')^2}{y_1}\cdot\frac{x''}{x'} + \frac{y_2 x'}{y_1}\left\{3\left(\frac{x''}{x'}\right)^2 + 4\,\frac{x'''}{x'}\right\} + \frac{x^{iv}}{x'}.$$

Hence, on account of (1), we have the invariant functions

$$\frac{y_2 x'}{y_1},\ \frac{y_3 (x')^2}{y_1},\ \frac{y_4 (x')^3}{y_1},$$

from which it is only necessary to eliminate x' in order to obtain our required differential invariants:

$$\phi_1 = \frac{y_1 y_3}{y_2^2},\ \phi_2 = \frac{y_4 y_1^2}{y_2^3}.$$

9. The general projective group in one variable

$$\boxed{q,\ yq,\ y^2 q}$$

leaves invariant x and $R = \dfrac{y^{(2)} - y^{(4)}}{y - y^{(4)}} : \dfrac{y^{(2)} - y^{(3)}}{y - y^{(3)}}$.

Using t, r, s as auxiliary variables, R takes the form, for ultimately coincident points

$$R = \frac{1 - \alpha}{1 - \beta} = (1 - \alpha)\,(1 + \beta + \beta^2 + \ldots),$$

where $\alpha = (y'\,dt + y''\,\frac{dt^2}{2} + \dots) : (y'ds + y''\,\frac{ds^2}{2} + \dots)$, and

$$\beta = (y'\,dt + y''\,\frac{dt^2}{2} + \dots) : (y'\,dr + y''\,\frac{dr^2}{2} + \dots).$$

Arranging R according to positive powers of dt, dr, ds, and omitting superfluous terms, we find

$$R \equiv \dots\, dt\,(ds - dr) \left\{ \frac{y'''}{6y'} - \left[\frac{y''}{2y'}\right]^2 \right\} + \dots$$

$$+ dt\,(ds^2 - dr^2) \left\{ \frac{y^{iv}}{24y'} - \frac{y''\,y'''}{6\,(y')^2} + \left[\frac{y''}{2y'}\right]^3 \right\} + \dots$$

$$+ dt\,(ds^3 - dr^3) \left\{ \frac{y^{v}}{120y'} - \frac{y''\,y^{iv}}{24\,(y')^2} - \left[\frac{y'''}{6y'}\right]^2 - \left[\frac{y''}{2y'}\right]^4 + \frac{(y'')^2\,y'''}{8\,(y')^3} \right\} + \dots$$

From these coefficients we may determine the differential invariants.

$$\phi_1 = x.$$

$$I_1 = \frac{y'''}{6y'} - \left(\frac{y''}{2y'}\right)^2 = \frac{(x')^2}{12}\,\frac{2y_1\,y_3 - 3y_2^2}{y_1^2} + \frac{x'''}{6x'} - \left(\frac{x''}{2x'}\right)^2,$$

$$\therefore \phi_2 = \frac{2y_1\,y_3 - 3y_2^2}{y_1^2}.$$

$$I_2 = \frac{(x')^3}{24}\left(\frac{y_4}{y_1} - \frac{4y_2\,y_3}{y_1^2} + \frac{3y_2^3}{y_1^3}\right) + \frac{x'\,x''}{24}\,\phi_2 + I_2\,(x),$$

$$\therefore \phi_3 = \frac{y_4}{y_1} - 4\,\frac{y_2\,y_3}{y_1^2} + 3\,\frac{y_2^3}{y_1^3}.$$

$$I_3 = \frac{(x')^4}{120}\left(\frac{y_5}{y_1} - 5\,\frac{y_2\,y_4}{y_1^2} - 4\,\frac{y_3^2}{y_1^2} + 17\,\frac{y_2^2\,y_3}{y_1^3} - 9\,\frac{y_2^4}{y_1^4}\right) +$$

$$+ \frac{(x')^2\,x''}{24}\cdot\phi_3 + \frac{(x')^4}{720}\,\phi_2^2 + \frac{x'\,x'''}{72}\,\phi_2 + I_3\,(x),$$

$$\therefore \phi_4 = \frac{y_5}{y_1} - 5\,\frac{y_2\,y_4}{y_1^2} - 4\left(\frac{y_3}{y_1}\right)^2 + 17\,\frac{y_2^2\,y_3}{y_1^3} - 9\left(\frac{y_2}{y_1}\right)^4.$$

In some of the following paragraphs we shall need the forms I_2, I_3, here computed. Incidentally we have computed the differential invariants ϕ_3, ϕ_4.

10. The group

$$\boxed{q,\ yq,\ y^2q,\ p}$$

has the same differential invariants as 9 above, with the exception of ϕ_1, which must be omitted. We shall have, therefore, ϕ_2, ϕ_3, ϕ_4, as defined above.

11. **By the group**

$$\boxed{q,\ yq,\ y^2q,\ p,\ xp}$$

the functions I_1, I_2, I_3 of 9 remain invariant, also $\frac{x''}{x'}, \frac{x'''}{x'}, \frac{x^{iv}}{x'}, \ldots$ as in 8. These invariant functions must be so manipulated that the x's are either eliminated or made to appear as ratios $\frac{x''}{x'}, \frac{x'''}{x'}, \ldots$ Since $I_1(x)$, $I_2(x)$ .... are already functions of $\frac{x''}{x'}, \frac{x'''}{x'}, \ldots$, we may omit these, and write simply

$$J_1 = \phi_2(x')^2,\ J_2 = \phi_3(x')^3 + \phi_2 x'x'',$$

$$J_3 = \phi_4 \frac{(x')^4}{5} + \phi_3(x')^2x'' + \phi_2{}^2 \frac{(x')^4}{30} + \phi_2 \frac{x'x'''}{3}.$$

Eliminating x', x'', ... ,

$$\left(J_2 : J_1 - \frac{x''}{x'}\right) : (J_1)^{\frac{1}{2}} \equiv \frac{\phi_3}{(\phi_2)^{\frac{3}{2}}} = \frac{\frac{y_4}{y_1} - \frac{4y_2 y_3}{y_1{}^2} + 3\left(\frac{y_2}{y_1}\right)^3}{\left\{\frac{2y_3}{y_1} - 3\left(\frac{y_2}{y_1}\right)^2\right\}^{\frac{3}{2}}} = \Phi_1 .$$

$$J_3 : J_1 \equiv \frac{\phi_4}{\phi_2} \cdot \frac{(x')^2}{5} + \frac{\phi_3}{\phi_2} x' \left(\frac{x''}{x'}\right) + \phi_2 \frac{(x')^2}{30} + \frac{x'''}{3x'}$$

$$= \frac{\phi_4}{\phi_2} \cdot \frac{(x')^2}{5} + \left(J_2 : J_1 - \frac{x''}{x'}\right) \frac{x''}{x'} + \frac{J_1}{30} + \frac{x'''}{3x'} .$$

Hence, $A \equiv \frac{\phi_4}{\phi_2} (x')^2$ is invariant.

$$A : J_1 = \frac{\phi_4}{\phi_2{}^2} = \frac{\frac{y_5}{y_1} - 5\frac{y_2 y_4}{y_1{}^2} - 4\left(\frac{y_3}{y_1}\right)^2 + 17\frac{y_2{}^2 y_3}{y_1{}^3} - 9\left(\frac{y_2}{y_1}\right)^4}{\left\{\frac{2y_3}{y_1} - 3\left(\frac{y_2}{y_1}\right)^2\right\}^2} = \Phi_2 .$$

Φ_1, Φ_2 are the two fundamental differential invariants.

12. It has been shown that the group

$$\boxed{\begin{array}{c} X_1(x)\, q,\ X_1(x) . q,\ X_3(x)\, q,\ \ldots .\ X_r(x) . q \\ r > 1 \end{array}}$$

leaves invariant x and the determinant

$$D = \begin{vmatrix} y & y^{(2)} & y^{(3)} & \ldots\ldots & y^{(r+1)} \\ X_1(x) & X_1(x^{(2)}) & X_1(x^{(3)}) & \ldots\ldots & X_1(x^{(r+1)}) \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ X_r(x) & X_r(x^{(2)}) & X_r(x^{(3)}) & \ldots\ldots & X_r(x^{(r+1)}) \end{vmatrix} .$$

We shall denote the parameters for $x^{(2)}$, $x^{(3)}$ .... by t, s, ..., respectively, and have series expansion for $X_i(x^{(2)})$ in the form

$$X_i(x^{(2)}) = X_i(x + x'dt + x''\frac{dt^2}{2} + x'''\frac{dt^3}{6} + ..)$$

$$= X_i(x) + X_i'(x).x'dt + \left[X_i''(x).x'^2 + X_i'(x).x''\right]\frac{dt^2}{2} +$$

$$+ \left[X_i'''(x).x'^3 + 3X_i''(x).x'x'' + X_i'(x).x'''\right]\frac{dt^3}{6} +$$

$$+ \left[X_i^{iv}(x).x'^4 + 6X_i'''(x).x'^2x'' + 3X_i(x).x''^2 + \right.$$

$$\left. + 4X_i''(x).x'x''' + X_i'(x).x^{iv}\right]\frac{dt^4}{24} + \ldots\ldots\ldots\ldots$$

with like expansions for $X_i(x^{(3)})$, ... in parameters s, ... Substituting these series expansions for X_i in the above determinant and subtracting vertical columns in a proper manner, we have

$$\begin{vmatrix} y & y_1x' + \ldots & y_2(x')^2 + \ldots & y_3(x')^3 + \ldots & \ldots\; y_{r+1}(x')^{r+1} + \ldots \\ X_1 & X_1'x' + \ldots & X_1''.(x')^2 + \ldots & X_1'''.(x')^3 + \ldots & \ldots\; X_1^{r+1}.(x')^{r+1} + \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ X_r & X_r'x' + \ldots & \ldots & \ldots & \ldots \end{vmatrix}$$

Or disregarding x', x'', ... which are invariant, and retaining only the elements of lowest degree in dt, ds, ..., we have

$$\Phi_1 = \begin{vmatrix} y & y_1 & y_2, & \ldots & y_{r+1} \\ X_1 & X_1' & X_1'', & \ldots & X_1^{r+1} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ X_r & X_r' & X_r'' & \ldots & X_r^{r+1} \end{vmatrix}.$$

Since x is also invariant, $\Phi^2 = \frac{d\Phi_1}{dx}$, which would be the above determinant with the last column changed to y_{r+2}, X_1^{r+2}, ... X_r^{r+2}.

13. $\boxed{X_1q,\ X_2q,\ \ldots\ldots\ X_{r-1}q,\ yq}$ leaves invariant x and the ratio $\phi_2 : \phi_1$, where ϕ_2, ϕ_1 are determinants defined in 12.

Since x also remains invariant, we may write our differential invariants

$$\Phi_1 = \frac{\phi_2}{\phi_1}.$$

$$\Phi_2 = \frac{d\Phi_1}{dx}.$$

14. The special linear group

$$\boxed{p,\ q,\ xq,\ xp - yq,\ yp}$$

has the point-invariant

$$D = \begin{vmatrix} x & y & 1 \\ x^{(2)} & y^{(2)} & 1 \\ x^{(3)} & y^{(3)} & 1 \end{vmatrix}.$$

Expressing $x^{(2)}, y^{(2)}$; $x^{(3)}, y^{(3)}$ in series expansion in terms of t, s,

$$D = \begin{vmatrix} x & y & 1 \\ x + x'\,dt + x''\frac{dt^2}{2} + \ldots., & y + y'\,dt + y''\frac{dt^2}{2} + \ldots., & 1 \\ x + x'\,ds + x''\frac{ds^2}{2} + \ldots., & y + y'\,ds + y''\frac{ds^2}{2} + \ldots., & 1 \end{vmatrix}$$

$$= I_1\frac{dt\,ds^2}{2} + I_2\frac{dt\,ds^3}{6} + I_3\frac{dt\,ds^4}{24} - I_4\frac{dt^2\,ds^2}{12} + I_5\frac{dt\,ds^5}{120} +$$

$$+ I_6\frac{dt^2\,ds^4}{48} + \ldots.,$$

where

$I_1 = x'y'' - x''y' = y_2(x')^3$,

$I_2 = x'y''' - x'''y' = y_3(x')^4 + 3y_2(x')^2x''$,

$I_3 = x'y^{iv} - x^{iv}y' = y_4(x')^5 + 6y_3(x')^3x'' + 3y_2x'(x'')^2 + 4y_2(x')^2x'''$,

$I_4 = x'''y'' - x''y''' = y_2[(x')^2x''' - 3x'(x'')^2] - y_3(x')^3x''$,

$I_5 = x'y^{v} - x^{v}y' = y_5(x')^6 + 10y_4(x')^4x'' + 15(x'x'')^2 + 10y_3(x')^3x''' +$
$\qquad + 10y_2x'x''x''' + 5y_2(x')^2x^{iv}$,

$I_6 = x''y^{iv} - x^{iv}y'' = y_4(x')^4x'' + 6y_3(x'x'')^2 + y_2[3(x'')^3 + 4x'x''x''' -$
$\qquad - (x')^2x^{iv}]$.

From these six invariant functions we eliminate the differentials $x'\ x''$, ... obtaining the differential invariants:

$$\Phi_1 = \left\{3\, I_1 I_3 - 12\, I_1 I_4 - 5\, I_2{}^2\right\} : (I_1)^{\frac{8}{3}} = (3y_2 y_4 - 5y_3{}^2) : y_2{}^{\frac{8}{3}}.$$

$$\Phi_2 = \left\{15\, I_1{}^2 I_6 + 3\, I_1{}^2 I_5 + \tfrac{40}{3}\, I_2{}^3 - 15\, I_1 I_2 (I_3 - 2\, I_4)\right\} : I_1{}^4$$

$$= \left\{3y_2{}^2 y_5 - 15 y_2 y_3 y_4 + \tfrac{40}{3}\, y_3{}^3\right\} : y_2{}^4.$$

15. The general linear group

$$\boxed{p,\ q,\ xq,\ xp - yq,\ yp,\ xp + yq}$$

leaves invariant the quotient

$$Q = \begin{vmatrix} x & y & 1 \\ x^{(2)} & y^{(2)} & 1 \\ x^{(3)} & y^{(3)} & 1 \end{vmatrix} : \begin{vmatrix} x & y & 1 \\ x^{(3)} & y^{(3)} & 1 \\ x^{(4)} & y^{(4)} & 1 \end{vmatrix}.$$

Using t, s, r as parameters of three successive points, we find

$$Q = \begin{vmatrix} x & y & 1 \\ x + x'dt + \dots & y + y'dt + \dots & 1 \\ x + x'ds + \dots & y + y'ds + \dots & 1 \end{vmatrix} : \begin{vmatrix} x & y & 1 \\ x + x'ds + \dots & y + y'ds + \dots & 1 \\ x + x'dr + \dots & y + y'dr + \dots & 1 \end{vmatrix}$$

$$= \left\{\begin{matrix} k_1 I_1 \mid dt\, ds^2 \mid + k_2 I_2 \mid dt\, ds^3 \mid + k_3 I_3 \mid dt\, ds^4 \mid + k_4 I_4 \mid dt^3 ds^2 \mid + \\ + k_5 I_5 \mid dt\, ds^5 \mid + k_6 I_6 \mid dt^2 ds^4 \mid + k_7 I_7 \mid dt\, ds^6 \mid + k_8 I_8 \mid dt^2\, ds^5 \mid + \\ + \mid k_9 I_9 \mid dt^3\, ds^4 \mid \end{matrix}\right\} :$$

$$: \left\{\text{Similar expression in ds, dr.}\right\},$$

where k_i are constants, $\mid dt^a\, ds^b \mid = \begin{vmatrix} dt^a & dt^b \\ ds^a & ds^b \end{vmatrix}$, and I_i are functions defined as in 14. The form of this expansion for Q shows at once the invariance of the quotients $I_2 : I_1$, $I_3 : I_1$, ... Denoting these ratios by R, we have

$$\begin{aligned}
R_2 &= I_2 : I_1 = (x'y''' - x'''y') : (x'y'' - x''y'), \\
R_3 &= I_3 : I_1 = x'y^{iv} - x^{iv}y') : I_1, \\
R_4 &= I_4 : I_1 = (x'''y'' - x''y''') : I_1, \\
R_5 &= I_5 : I_1 = (x'y^{v} - x^{v}y') : I_1, \\
R_6 &= I_6 : I_1 = (x''y^{iv} - x^{iv}y'') : I_1, \\
R_7 &= I_7 : I_1 = (x'y^{vi} - x^{vi}y') : I_1, \\
R_8 &= I_8 : I_1 = (x''y^{v} - x^{v}y'') : I_1, \\
R_9 &= I_9 : I_1 = (x'''y^{iv} - x^{iv}y''') : I_1.
\end{aligned}$$

In these eight functions we must express y^1 in terms of y_1 and x^1, and then eliminate the differentials x', x'', ... This work of elimination is quite tedious, but may be briefly indicated. We construct three functions.

$$A \equiv 3\,R_3 - 12\,R_4 - 5R_2{}^2 = \frac{3y_2y_4 - 5y_3{}^2}{y_2{}^2}\,(x')^2.$$

$$B \equiv 15\,R_6 + 3R_5 + \frac{40}{3}\,R_2{}^3 - 15\,R_2\,R_3 + 30\,R_2\,R_4$$

$$\equiv \frac{3y_2{}^2y_5 - 15y_2y_3y_4 + \frac{40}{3}\,y_3{}^3}{y_2{}^3}\,(x')^3,$$

$$C \equiv 18R_8 + 3R_4 - 60\,R_9 - 21\,R_2\,R_5 - \tfrac{35}{3}\,R_2{}^4 + 35\,R_2{}^2R_3 + 70\,R_2{}^2R_4 + 210R_4{}^2$$

$$\equiv \frac{3y_2{}^3y_6 - 21y_2{}^2y_3y_5 + 35\,y_2\,y_3{}^2y_4 - \frac{35}{3}\,y_3{}^4}{y_2{}^4}\,(x')^4,$$

and eliminate from these x', giving the differential invariants

$$\Phi_1 = (3y_2{}^2y_5 - 15\,y_2y_3y_4 + \tfrac{40}{3}\,y_3{}^3) : (3y_2y_4 - 5y_3{}^2)^{\frac{3}{2}}$$

$$\Phi_2 = (3y_2{}^3y_6 - 21\,y_2{}^2y_3y_5 + 35y_2y_3{}^2y_4 - \tfrac{35}{3}\,y_3{}^4) : (3y_2y_4 - 5y_3{}^2)^2.$$

MATHEMATICAL DEFINITIONS. BY MOSES C. STEVENS.

PERFORMANCE OF THE TWENTY-MILLION-GALLON SNOW PUMPING ENGINE OF THE INDIANAPOLIS WATER COMPANY. BY W. F. M. GOSS.

The fact that a pumping engine recently installed within the State of Indiana has given a duty performance higher than that previously reported for any pumping engine in any country is deemed of sufficient moment to merit the attention of the Academy.

This engine was built by the Snow Steam Pump Works of Buffalo, N. Y., and its installation at the Riverside station of the Indianapolis Water Company was completed in season for an acceptance test in July, 1898. It is a triple-expansion, fly-wheel engine, having a single acting pump below and in line with each of the three steam cylinders. Its principal dimensions are as follows:

Diameter of cylinders:	*Inches.*
High pressure	29
Intermediate	52
Low pressure	80

	Inches.
Diameter of piston rods:	
High pressure	6
Intermediate	7
Low pressure	8
Diameter of pump plunger (three single acting)	33
Stroke of all pistons and plungers	60

The more important conditions prevailing during the test of July 5 were substantially those of every-day service, and were as follows:

Revolutions per minute	21.5
Steam pressure	155.6
Total pressure against which pumps were operated (water pressure against which pumps delivered, plus suction lift,) pounds	88.7
Indicated horse power	775.5

Under these general conditions it was found that the engine performed 11,725,000,000 foot-pounds of work at the pump, on a consumption of 79,-093,000 British thermal units, giving a duty per million B. T. U. of 150.1 million foot-pounds, a performance which, as already noted, exceeds by a liberal margin that obtained in any test, the results of which have thus far been published. A comparison of the performance of this engine with that of two other famous engines is as follows:

Name of designer or builder	E. P. Allis Co.	E. D. Leavitt, Jr.	Snow Steam Pump Works.
Locality	Milwaukee, Wis.	Chestnut Hill, Mass	Indianapolis, Ind.
Type	Triple expansion.	Triple expansion.	Triple expansion.
Name of expert conducting test	Prof. R. C. Carpenter	Prof. E. F. Miller.	Prof. W. F. M. Goss.
Capacity—million gals. in 24 hours	18	20	20.
Indicated horse power, I. H. P.	573.9	575.7	775.5.
Duty based on 1,000,000 heat units, expressed in million foot-pounds	137	141.9	150.1.

The work incident to the test was advanced by careful, painstaking and conservative methods, and it was believed at the time that the results obtained were as worthy of confidence as those ordinarily derived from such work. In view, however, of the remarkable performance obtained, and to avoid any possible questioning concerning the performance of the

engine, the Indianapolis Water Company, with great liberality, arranged for a second test which should be so complete as to admit of a thorough analysis of its action. This second test was run early in the present month (December 3, 1898), and, while all the facts to be derived from it have not yet been determined, enough is known of them to make certain the accuracy of the previous work. The exceptional performance of the engine having, therefore, been carefully established, it is evident that the engine represents a very high standard of engineering practice. It marks the engineering progress of the day. This makes it not only a machine in which its owners may take just pride, but one which lends lustre to the whole State.

Tests to Determine the Efficiency of Locomotive Boiler Coverings.

By W. F. M. Goss.

The extent of heat losses occurring by radiation from a modern locomotive boiler under service conditions has long been a matter of speculation. There have been many investigations to determine the radiation from pipes and other steam heated surfaces, usually within buildings, but until recently no tests have been made which would disclose the effect of the air currents which, at speed, circulate about a locomotive boiler.

During the past summer (1898), however, Mr. Robert Quayle, Superintendent of Motive Power of the Chicago and Northwestern Railroad Company, in co-operation with manufacturers of boiler coverings, and, with the assistance of the undersigned, undertook to determine both the heat losses from a boiler and the relative value of several different makes of boiler coverings designed to reduce such losses. The following is a brief abstract of a report of results submitted to Mr. Quayle:

In carrying out the tests, two locomotives were employed; one to be hereafter referred to as the "experimental locomotive" was subject to the varying conditions of the test; the other being under normal conditions and serving to give motion to the experimental locomotive, and, also, as a source of supply from which steam could be drawn for use in maintaining the experimental boiler at the desired temperature. The experimental locomotive was coupled ahead of the normal engine, and, consequently,

was first when running to enter the undisturbed air. The action of the air currents upon it, therefore, was in every way similar to those affecting an engine doing ordinary work at the head of a train.

The boiler of the experimental locomotive was kept under a steam pressure of 150 pounds by a supply of steam drawn from the boiler of the normal engine in the rear. There was no fire in the experimental boiler, which at all times was practically void of water. Precautions were taken which justified the assumption that all water of condensation collecting in the experimental boiler was the result of radiation of heat from its exterior surface. This water of condensation was collected and weighed, thus serving as a means from which to calculate the amount of heat radiated.

The dimensions of the experimental boiler are shown by Table I:

TABLE I.

Dimensions of Boiler.

Diameter, in inches	52
Heating surface (square feet)	1,391
Total area of exterior surface, not including surface of smoke box	358
Area of surface covered (square feet)	219
Area of steam heated exposed surface not covered	139
Ratio of surface covered to total surface	.61

The results of the tests, briefly stated, are shown in Table II:

TABLE II.

Pounds of Steam at 150 Pounds Pressure Condensed per Minute.

Bare boiler at rest	6.8
Bare boiler moving at a uniform speed of 28.3 miles per hour	14.3
Boiler covered in the usual way with approved material—61 per cent. of the total surface only being protected—at rest	3.0
Boiler covered in the usual way with approved material—61 per cent. of the total surface only being protected—moving at a uniform speed of 28.3 miles per hour	5.3

Assuming a rate of steam consumption by engine, and an evaporative efficiency of the boiler which represent results obtained in fair, average practice, the heat losses disclosed by the preceding figures may be transformed into power losses, which are as follows:

TABLE III.

Horse-Power Equivalent of Heat Radiated from Boiler.

Bare boiler, locomotive at rest	12
Bare boiler, locomotive running 28.3 miles per hour	25
Boiler covered with approved material in a manner common to good practice, locomotive at rest	4.5
Boiler covered with approved material in a manner common to good practice, locomotive running 28.3 miles per hour	9.3

Again, the results obtained afford a basis from which calculations may be made to show the extent of losses which will occur when the locomotive is run at higher speeds and under lower atmospheric temperatures. For example, it can be shown that had the boiler tested been run at a speed of eighty miles an hour under a steam pressure of 200 pounds, when the atmospheric temperature is 0 degrees, it would, if bare, have radiated an amount of heat which is the equivalent of sixty-seven horse power, and if covered in the most approved manner it would have radiated an amount of heat which is the equivalent of twenty-five horse power.

It will be seen that the radiation losses are quite sufficient to merit the earnest attention of those interested in improving the performance of locomotives.

THE LEONIDS OF 1898. BY JOHN A. MILLER.

As the results of the observations of the Leonid shower of 1898, made at various places in the United States, are accessible, this note shall only have to do with the observations made at Bloomington, Indiana.

We limited ourselves chiefly to two classes of observations. First, the determination of the number of Leonids that fell during certain periods of time between November 12 and November 19. We hoped from this data

to determine the density and the width of the stream at this point in its path. We had prepared a circular map of the sky with a radius of about 32° and a center near γ Leonis, and confined our watch to this portion of the heavens. The following table exhibits the results of these observations. It should be added, however, that these observers were making their first meteor observations and that their judgment as to whether a given meteor was a Leonid or non-Leonid was probably in many instances prejudiced in favor of the former. Hence I am inclined to believe that about eighty per cent. of the meteors observed were Leonids; the remainder belonged to other streams.

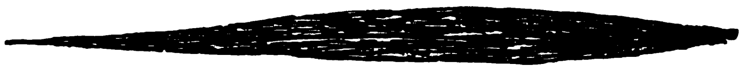
Date.	Period Begins.	Period Ends.	Number of Meteors.	Condition of Sky.	Remarks.
November 12.	4.00 a.m.	4.30 a.m.	15	Cloudless	No distinction as to class of meteors
November 12..	4.30 a.m.	5.00 a.m.	21	Cloudless	No distinction as to class of meteors
November 12..	11.00 p.m.	12.00 m.	......	Cloudy	
November 13..	11.00 p.m.	12.00 m.	......	Cloudy	
November 14..	12.01 a.m.	4.00 a.m.	......	Cloudy	Not a break in the sky.
November 14..	4.00 a.m.	5.00 a.m.	2	Cloudy	Only a small patch of sky visible.
November 14..	11.00 p.m.	12.00 p.m.	41	Cloudless	
November 15..	12.11 a.m.	12.30 a.m.	20	Cloudless	
November 15..	12.30 a.m.	12.45 a.m.	18	Cloudless	
November 15..	12.45 a.m.	1.00 a.m.	14	Cloudless	
November 15.	1.00 a.m.	1.15 a.m.	14	Cloudless	
November 15..	1.15 a.m.	1.30 a.m.	22	Cloudless	
November 15..	1.30 a.m.	1.45 a.m.	22	Cloudless	
November 15..	2.00 a.m.	2.15 a.m.	20	Cloudless	
November 15..	2.50 a.m.	3.05 a.m.	27	Cloudless	
November 15..	4.10 a.m.	4.30 a.m.	28	Cloudless	Of these, 25 were certainly Leonids.
November 15..	10.30 p.m.	11.20 p.m.	None	Cloudless	
Nov. 15–16.....	11.50 p.m.	12.25 a.m.	1	Cloudless	This was a Leonid.
November 16..	4.30 a.m.	5.00 a.m.	6	Cloudless	These were Leonids.
November 19..	1.00 a.m.	1.30 a.m.	1	Cloudless	This was a Leonid. It was as bright as Regulus.

On November 15, at 3:02 a. m., a green point of light appeared in the sickle at about right ascension 10h and declination 22°. Gradually the point of light seemed to spread until it covered an area. In a few seconds

this area faded slowly and disappeared. It was the only stationary meteor that we observed.

Many meteors were observed that appeared outside the region covered by the map. These are not included in the foregoing table. For example: I watched the region surrounding Orion (not in the map) from 1:45 to 2:00 a. m., November 15. Fifteen bright Leonids were observed.

The meteors were rarely as bright as the first magnitude stars. The longest trail that we saw was about 110° long, but the average length was not more than 20°. The accompanying figure is that of a normal Leonid as I saw them.



The head of the brightest meteors seemed globular, and to be slightly separated from the tail as if it were surrounded by an envelope of non-luminous gas. The globular appearance was doubtless due to irradiation. The color of the head was generally yellowish red, a little more yellow than Mars, suggestive of a heated iron passing from a white-hot to a red-hot temperature. The tail or train was blue or green. The brighter the tail the greener it appeared. It seemed to me, also, that the brighter trains had a bright, narrow, perfectly straight streak or spine, exactly in the middle of the tail, and in the path described by the head. That whatever cause produced the tail was more intense in the broad part, is shown by the fact that the broad part faded out last, and in case of a very bright meteor some seconds after the head had disappeared.

Our second object was to obtain a permanent record of the paths described by the meteors, and to determine the radiant. To this end we platted the paths on the maps as the meteors fell. In all about 225 paths were platted on four different maps. The paths were then produced. Many of them intersected in a comparatively small area. The average of four determinations for the radiant gave Right ascension=9h, 45m; Declination=21°, 40m.

The number of Leonids that fell during the last shower was not so large as anticipated. This augurs well for a large shower November 13-16, 1899. The observations also show that the stream is wider than formerly supposed.

A Linear Relation Between Certain of Klein's X Functions and Sigma Functions of Lower Division Value. By John A. Miller.

Professor Felix Klein has defined a system of interesting functions by the following equation*:

$$X_{\frac{a}{m}}(u) = C_a \prod_{\mu=0}^{m-1} \sigma_{\frac{a}{m}+e,\ \frac{\mu+e}{m}}(u \mid \omega_1, \omega_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where $\varepsilon = 0$, or $\frac{1}{2}$, according as m is odd or even, and

$$\sigma_{\frac{\lambda}{m},\frac{\mu}{m}}(u \mid \omega_1, \omega_2 = e^{\left\{\frac{\lambda\eta_1 + \mu\eta_2}{m}\right\}\left\{\frac{u - \lambda\omega_1 + \mu\omega_2}{2m}\right\}} \sigma\left(u - \frac{\lambda\omega_1 + \mu\omega_2}{m} \mid \omega_1, \omega_2\right) \ldots (2)$$

u is the fundamental variable of the elliptic functions, ω_1, ω_2 the periods of an elliptic integral of the first kind, η_1, η_2 the periods of an elliptic integral of the second kind, C_a, a quantity independent of u and $\sigma(u \mid \omega_1, \omega_2)$ is the ordinary Weierstrassian σ-function and where λ, μ and m are integers.

I shall now prove that in the case m is a square number, *i. e.*, $m = n^2$ that $X_{\frac{a}{n^2}}(u)$ *can be expressed as a linear homogeneous function of* $\sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$.

To do this, we need the so-called *Hermite Law*† which, when specialized to meet our needs, is as follows:

Suppose we are given n quantities defined as follows:

$$x_i = C_i \prod_{j=1}^{n} \sigma(u - a_{i,j}) \qquad (i = 1 \,..\, n)$$

such that the sum of the zero points in the period parallelogram of the μ-plane is,

$$S = \Sigma a_i,\ j = 0,$$

And, suppose that we are given a σ-product,

$$P = f(\omega) e^{(\lambda n_1 + u n_2)\left(u + \frac{\lambda\omega_1 + u\omega_2}{2}\right)} \prod_{i=1}^{n} (u - u_i)$$

Such that the sum of the vanishing points of P in the period parallelogram of the u-plane is

$$\sum_{i=1}^{n} u_i = \lambda\omega_1 + \mu\omega_2$$

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* See Felix Klein: "Vorlesungen über die Theorie der Elliptischen Modulfunctionen," Zweiter Band, p. 261, equation 1.

† F. Klein, Elliptische Normal-Curven und Modeln nter Stufe, p. 355, or Crelle's Journal, Band XXXII, Hermites, Lettre à Mr. Jacobi.

Then P can be expressed as a linear homogeneous function of x_1.

Proof:

$$* \sigma(nu \mid \omega_1; \omega_2) = f(\omega_1, \omega_2) \Pi \sigma\left(u - \frac{m_1 \omega_1 + m_2 \omega_2}{n} \mid \omega_1, \omega_2\right).$$

$$e^{\left(\frac{\eta_1 + \eta_2}{2}\right) n(n-1) u} \ldots\ldots\ldots\ldots \quad (3)$$

$$m_1, m_2 = 0 \ldots n-1$$

$$\sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(nu, \mid \omega_1, \omega_2) = e^{\left(\frac{\lambda n_1 + \mu n_2}{n}\right)\left(nu - \frac{\lambda\omega_1 + \mu\omega_2}{2n}\right)} \sigma\left(nu - \frac{\lambda\omega_1 + \mu\omega_2}{n} \mid \omega_1, \omega_2\right)$$

$$\therefore \sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(nu \mid \omega_1, \omega_2) =$$

[From (2)

$$e^{\frac{(\lambda n_1 + \mu n_2)}{n}\left(nu - \frac{\lambda\omega_1 + \mu\omega_2}{2n}\right)} e^{\frac{\eta_1 + \eta_2}{2} \cdot n \cdot (n-1)\left(u - \frac{\lambda\omega_1 + \mu\omega_2}{n^2}\right)}$$

$$\cdot f_1(\omega_1, \omega_2) \prod_{\substack{m_1 \\ m_2}\} = 0}^{n-1} \sigma\left(u - \frac{\lambda\omega_1 + \mu\omega_2}{n^2} - \frac{m_1\omega_1 + m_2\omega_2}{n} \mid \omega_1, \omega_2\right)$$

from equations (2) and (3).

Whence $\sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$ is a σ-product of n^2 factors.

Whose residue sum,

$$S = \lambda\omega_1 + \mu\omega_2 + n\frac{(n-1)}{2}\omega_1 + n\frac{(n-1)}{2}\omega_2;$$

moreover there are n^2 different quantities

$$\dagger \sigma_{\frac{\lambda}{n}, \frac{\mu}{n}}(n\,u \mid \omega_1, \omega_2).$$

If now, m define n^2 quantities

$$x_i = C_{i,} \prod_{j=0}^{n^2-1} \sigma(u - u_2 j) \ldots\ldots\ldots\ldots 5$$

Such that $\sum_{j=0}^{n_2-1} a_{i,j} = 0 \quad (i = 0 \ldots n^2 - 1)$

* Jord... ...'Analyse,'' Tome 2, p. 388.

† K... ...gen über die Theorie der Ellip...

II, p...

then by Hermites Law, each of the n^2 $\sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$

can be expressed as a linear homogeneous function of x_i.

We must now divide our discussion into two cases (a)
$n \equiv 1 \pmod{2}$

$$X_{\frac{a}{n^2}}(u) = f_1(\omega_1, \omega_2) \prod_{\mu=0}^{n^2-1} \sigma_{\frac{a}{n^2}, \frac{\mu}{n^2}}(u \mid \omega_1, \omega_2)$$

$$= f_3(\omega_1, \omega_2)\, e^{a\eta_1 + \left(\frac{n^2-1}{2}\right) \eta_2 \left(u - \left(a\omega_1 + \frac{\eta^2 - 1}{2}\omega_2\right)\right)}$$

$$\cdot \prod_{\mu=0}^{n^2-1} \sigma\left(u - \frac{a\omega_1 + \mu\omega_2}{n^2} \mid \omega_1, \omega_2\right),$$

Whence $X_{\frac{a}{n^2}}(u)$ is a σ-product of n^2 factors whose residual sum

$$S = a\omega_1 + \frac{n^2-1}{2}\omega_2.$$

And hence can be expressed as a linear function of x_1 defined in equation (4).
* There are n^2 quantities $X_{\frac{a}{n^2}}(u)$.

We have now shown that we can express the n^2 quantities $X_{\frac{a}{n^2}}(u)$ as linear homogeneous functions of x_1, and also the n^2 quantities $\sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$ as linear homogeneous functions of x_i, whence we can express $X_{\frac{a}{n^2}}(u)$ as a linear homogeneous function of $\sigma_{\frac{\lambda}{n},\frac{\mu}{n}}(nu \mid \omega_1, \omega_2)$.

Q. E. D.

(b) $n \equiv 0 \pmod{2}$.

In this case,

$$X_{\frac{a}{n^2}}(u) = f(\omega_1, \omega_2) \prod_{\mu=0}^{n^2-1} \sigma_{\frac{a}{n^2}+\frac{1}{2}, \frac{\mu+\frac{1}{2}}{n^2}}(u \mid \omega_1 \omega_2) \qquad \text{(Equation (1)}$$

$$= f_1(\omega_1, \omega_2) e^{\left\{n^2\left(\frac{a}{n^2}+\frac{1}{2}\right)\eta_1 + \frac{n^2}{2}\cdot\eta_2\right\}\left\{u - \frac{n^2\left(\frac{a}{n^2}+\frac{1}{2}\right)\omega_1 + \frac{n^2}{2}\omega_2}{2}\right.}$$

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* Klein: Vorlesungen, etc., Vol. II, p. 264.

$$\cdot \prod_{\mu=0}^{n^2 -} \sigma\left(u - \frac{a\,\omega_1 + \mu\,\omega_2}{n_2} \,\middle|\, \omega_1, \omega_2\right)$$

Whence $X_{\frac{a}{n^2}}(u)$ is a σ-product of n^2 factors whose residue sum,

$S = a\,\omega_1 + \frac{n^2 - 1}{2}\,\omega_2$ and hence can be expressed as a linear homogeneous function of x i defined in equation (4)

By repetition of the argument made in case (a) it follows that $X_{\frac{a}{n^2}}(u)$ can be expressed as a linear homogeneous function of $\sigma_{\frac{\lambda}{u}, \frac{\mu}{n}}(nu \mid \omega_1\, \omega_2)$.

Hence our proposition is proved for all integral values of n.

A Formula for the Deflection of Car Bolsters.* By W. K. Hatt.

The body bolster of a car is a beam which carries the weight of the car and its loading and transfers this weight to the center of the truck bolster, which, in turn, transfers the weight to the wheels.

The bolsters are either of trussed form or of beam form. In the latter case they are of I section or else with one flange and web plates.

It is quite important to construct the body bolster so that it may be stiff enough to prevent contact at the side bearings. These side bearings are placed between the truck and body bolster to limit the oscillations of the car. Evidently if the side bearings come into contact the consequent friction will offer additional resistance when the car goes around curves.

The problem is to compute the deflection of a beam of variable depth.

In case of beam bolsters the moment of inertia of the cross section may be taken to be a linear function of the distance of the cross section from the free end of the beam.

Referring to Fig. 1, let AB be one-half of a body bolster and OB the curve into which the half-bolster is bent. Any point of this curve is located with reference to O by its co-ordinates x y; mn is a section of the bolster distant x from O;

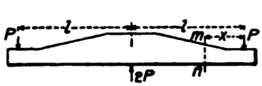

Fig. 4.

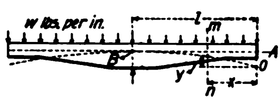

Fig. 1.

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*The following is an abstract of a paper which is given in complete form in the Railroad Gazette for December 23, 1898.

l is half the length of the bolster. Let I_0 be the moment of inertia at A, I^1 the moment of inertia at B and I the moment of inertia at the invariable section mn.

Assume the bolster to be uniformly loaded, to be supported at a point and also assume that the moment of inertia I at mn

$$= I_0 + \left\{\frac{I^1 - I_0}{l}\right\} x:$$

that is, the moment of inertia increases directly as x increases.

E is the modulus of elasticity of the material.

Equating the moment of the elastic forces to the moment of the external forces about the neutral axis of section mn, we find

$$+ E I \frac{d^2 y}{d x^2} = - \frac{w x^2}{2}$$

$$\text{or, } E \frac{d^2 y}{d x^2} = - \frac{w}{2} \cdot \frac{x^2}{I} = - \frac{w}{2} \cdot \frac{x^2}{I_0 + \left\{\frac{I^1 - I_0}{l}\right\} x}.$$

Dividing the enumerator of the fraction by the denominator, integrating twice and determining the value of the constants, we find

$$E y = \tfrac{1}{2} \frac{w l^4}{I^1 - I_0} \Big\{ n\Big[\tfrac{1}{2} - C + C^2 \Big\{1 + \log._e \left(\frac{1 + C}{n + C}\right)\Big\}\Big]$$

$$+ C^3 \log._e \left(\frac{C}{n + C}\right) + \frac{C n^2}{2} - \frac{n^3}{6}\Big\} \ldots\ldots\ldots\ldots\ldots\ldots (A)$$

$$\text{where } n = \frac{x}{l}, \text{ and } C = \frac{I_0}{(I^1 - I_0)}$$

To obtain the deflection at the side bearing, it would be necessary to substitute for n its proper numerical value along with other values, and compute the resulting value of y. The deflection at the side bearing is not equal this value of y; but is equal to the end deflection minus this value of y.

When $n = 1$,

$$E y = \frac{w l^4}{2(I^1 - I_0)} \left\{ \tfrac{1}{3} - \frac{C}{2} + C^2 + C^3 [\log._e I_0 - \log._e I^1] \right\}$$

When $n = 1$ and $I_0 = 0$,

$E y = \frac{w l^4}{6 I^1}$, and when $n = 1$ and $I_0 = I^1$ the expression becomes indeterminate and evaluates to $E y = \frac{w l^4}{8 I^1}$.

The truck bolster may be treated as a cantilever, with a terminal load equal to one-half the center load and a length one-half the length of the bolster as shown in Fig. 4.

If $I = I_0 + \left\{\frac{I^1 - I_0}{l}\right\} x$

then, $E \frac{d^2 y}{d x_2} = -\frac{P x}{I} = -\frac{P x}{I_0 + \left[\frac{I^1 - I_0}{l}\right]}$

Integrating this equation twice and determining the value of the constants, it becomes

$$E y = \frac{P l_3}{I^1 - I_0} \left\{ n \left[1 - C \left(\log._e \left(\frac{1 + C}{n + C} \right) + 1 \right) \right] \right.$$

$$\left. - C^2 \log._e \frac{C}{C + n} - \frac{n^2}{2} \right\} \text{......................(B)}$$

$$\text{Where } n = \frac{x}{l} \text{ and } C = \frac{I_0}{I^1 - I_0}.$$

When $n = 1$,

$$E y = \frac{P l^3}{I^1 - I_0} \left\{ \frac{1}{2} - C + C^2 (\log._e I^1 - \log._e I) \right\}.$$

If $I_0 = 0$ and $n = 1$

$$E y = \frac{1}{2} \frac{P l^3}{I^1}$$

When $I^1 = I_0$ and $n = 1$, the expression becomes an indeterminate form which evaluates to $y = \frac{1}{3} \frac{P l^3}{E I_0}$; which is a well-known formula.

Applying formula (A) to a body bolster, uniform load, when $I^1 = 115$, $I_0 = 28$, $l = 53$ in.; n for side bearing $= \frac{23}{53}$, $E = 30{,}000{,}000$, $w = 750$ pounds per running inch, we find that the deflection of side bearing below center $= 0.117$ inches. This same bolster subjected to actual test showed a deflection at side bearing, under above conditions, of 0.115 inches.

In this case, a close approximation to the deflection at side bearing will be given by the expression

$$d = \frac{1}{15} \frac{w l^4}{E I^1}$$

The method of loading a body bolster for the purpose of a laboratory test used in Purdue University laboratory, may be worth noting.

A wire is stretched between the side bearings, and the bolster is loaded near the ends. The movement of the wire with reference to the center is noted. The bolster is next loaded at points between the ends and the center. Successive loadings are thus applied and the consequent deflections of side bearings noted. Since the deflections are all elastic deflections, the sum of the individual deflections for part loadings may be taken without error to be the total deflection under the sum of the loadings.

Camphoric Acid: Reduction of the Neighboring Xylic Acid.

By W. A. Noyes.

[Abstract.]

An account of the preparation of the neighboring xylic acid has been recently given by the author in the American Chemical Journal. The acid has now been reduced to the corresponding hexahydroxylic acid. The latter boils at 250°—252°, while dihydrociscampholytic acid boils at 244°. The α-brom derivative has also been prepared and treated with alcoholic potash. The resulting acid is not ciscampholytic acid. This proves that Collie's formula for camphor cannot be true.

α-Hydroxy-dihydro-ciscampholytic Acid. By W. A. Noyes and J. W. Shepherd.

[Abstract.]

After many ineffectual attempts to prepare the acid by usual methods, it was finally obtained by shaking the ethyl ester of α-brom-dihydro-ciscampholytic acid for a long time, at a temperature of 40°—50°, with a strong aqueous solution of barium hydroxide. When the hydroxy acid is warmed with phosphoric acid and lead peroxide (a reaction for α-hydroxy acids, recently developed by Baeyer), it gives a ketone which is probably identical with that prepared by Mr. E. B. Harris, under the direction of one of us some years ago. We hope to secure the ketone in larger quantities and that a study of its derivatives will throw new light on the structure of camphor.

Iodine Absorption of Linseed Oil.* By P. N. Evans and J. O. Meyer.

The following statement concerning the necessary excess of iodine and the duration of the reaction, in determining the iodine absorption of oils, occurs in the 1897 edition (German) of Benedikt's "Analysis of Fats and Waxes" (page 152):

*This paper is an abstract of a thesis presented by Mr. J. O. Meyer, for the degree of B. Sc., and placed in the library of Purdue University.

"The [iodine] numbers are quite constant if the iodine solution is present in sufficient excess; the excess, according to Ulzer, when the reaction continues for six hours, must be at least 50 per cent. of the iodine used. Fahrion uses an excess of 100 per cent. of the absorbed iodine (i. e., also 50 per cent. of the iodine used) with a reaction of only two hours, and Holde recommends for this period of reaction the use of 75 per cent. excess of iodine. * * * With a sufficient excess of iodine the results obtained are the same after two hours, six hours, and longer periods."

This refers to the use of the ordinary Hübl's solution of iodine and mercuric chloride, and in the experiments to be described the determinations were carried out in the usual way, varying the two factors—(1) excess of iodine, and (2) duration of reaction.

Excess of Iodine.—It is stated in the passage above quoted that the iodine in excess must be at least 75 to 100 per cent. of the iodine absorbed, and that a larger excess will not affect the results if the reaction is not less than two to six hours in duration.

To test this statement the writers made twenty determinations with a linseed oil, the mixture being allowed to stand six hours, and the excess of iodine ranging from .008 to 3.658 per unit of iodine absorbed. The experiments were made in three series, each series being carried out under as nearly as possible identical conditions, and in spite of two slight discrepancies in the twenty experiments, there was unmistakable evidence that the iodine number steadily and materially increased with the excess of iodine, the increase being nearly as marked between an excess of 1 and of 3.6 as below 1. The iodine numbers obtained varied from 131.2 to 175.3, those with an excess of over 1 from 161.9 to 175.3.

Benedikt gives as minimum and maximum results for commercial linseed oil, according to twenty authorities, 148 and 181, with an average of 170.

Duration of Reaction.—In the above citation from Benedikt, a duration of two hours is said to be sufficient if the excess of iodine is equal to that absorbed (Fahrion), or 0.75 times as great (Holde), while six hours is said to be enough for an excess of 1 according to Ulzer.

The writers carried out eighty experiments to test this point, the excess of iodine varying from .5 to 1.4, and the duration of the reaction from two to eight hours. The eighty experiments were made in six series, and only three of the eighty experiments failed to confirm the conclusion that

six hours is not long enough to yield satisfactory results. The iodine numbers obtained ranged from 131 to 184.3.

These results seem to show that the figures given by Benedikt for excess of iodine and duration of reaction are too low, and point to those as preferable which are elsewhere recommended by Schweitzer and Lungwitz, Holde and Dieterich, summed up by A. H. Gill in his "Short-Handbook of Oil Analysis," as follows: "The excess of iodine recommended is from 150 to 250 per cent.; some observers recommend from 400 to 600 per cent. * * * Two hours is sufficient for olive oil, tallow and lard, while for linseed oil, balsams and resins, twenty-four hours should be allowed.

TABLE I.

Showing Effect of Excess of Iodine.

Series No.	Number of Nearly Identical Experiments.	Average Excess of Iodine per 1 Absorbed.	Duration of Reaction.	Average Iodine Number Found.
	3	.009	6 hours	131.2
1	2	.341	6 hours	147.9
	3	.737	6 hours	151.6
2	3	2.888	6 hours	161.9
	3	3.648	6 hours	162.4
	2	1.503	6 hours	172.3
3	2	1.954	6 hours	175.3
	2	3.075	6 hours	173.3

TABLE II.

Showing Effect of Duration of Reaction.

	3	.589	2 hours	165.0
1	3	.566	4 hours	168.0
	3	.540	6 hours	170.7
	3	.526	8 hours	172.3
	3	.740	2 hours	155.4
	3	.624	3 hours	156.4
2	3	.638	4 hours	158.3
	2	.444	6 hours	159.8
	3	.498	8 hours	160.8

TABLE II—CONTINUED.

3	3	.637	2 hours	162.4
	3	.601	4 hours	166.4
	3	.584	6 hours	167.9
	3	.557	8 hours	170.9
4	3	.655	2 hours	175.3
	3	.618	4 hours	179.1
	3	.610	6 hours	182.9
	3	.589	8 hours	184.3
5	3	.951	2 hours	131.9
	3	.940	3 hours	133.4
	3	.951	4 hours	131.0
	3	.896	6 hours	134.4
	3	.889	8 hours	134.6
6	3	1.535	2 hours	165.8
	3	1.495	3 hours	168.2
	3	1.493	4 hours	168.8
	3	1.453	6 hours	170.8
	3	1.396	8 hours	171.5

Some Desmids of Crawfordsville. By Mason B. Thomas.

In looking over the bibliography of Indiana cryptogams we have been greatly surprised at the very meager representation of our Algæ. This we believe to be in some measure due to the lack of correlation of work already done in different parts of the State and upon which no report has been made.

The past spring one of our students, Mr. F. Corey, in working on some Algæ made a list of Desmids that we believe worth while to record. Nothing need be said about the list except that the determinations were carefully made and mounted specimens preserved of each form, together with notes on distribution, etc. It is the intention to prepare as complete a list as possible of Crawfordsville Algæ with a view to some studies on distribution. Permit us to suggest that

other records of such work should be presented for the benefit of those working on this group. Personally we should appreciate any such contribution as bearing on some work now in hand.

Closterium lanceolatum, Kg.,
Closterium moniliferum, Ehrb.,
Closterium Leibleinii, Kg., Var. *curtum*, West.

Staurastrum muticum, Berb.
Staurastrum botrophilum, Wolle.

Calocylindrus Thwaitesii, Ralfs.

Penium Berbissonii (Mengh), Ralfs.
Penium margaritaceum, Berb.

Cosmarium pseudobroomei, Wolle.
Cosmarium granatum, Berb.
Cosmarium speciosum, Lund.
Cosmarium Holmiense, Var. *integrum*, Lund.
Cosmarium polymorphum, Nord.
Cosmarium Naegelianum, Berb.
Cosmarium Cordanum, Berb.

KARYOKINESIS IN THE EMBRYO-SAC WITH SPECIAL REFERENCE TO THE BEHAVIOR OF THE CHROMATIN. BY D. M. MOTTIER.

[Published in Jahrb. für wiss. Botan., Bd. XXX, 1897.]

NUCLEAR DIVISION IN VEGETATIVE CELLS. BY DAVID M. MOTTIER.

[Abstract.]

In my paper "Ueber das Verhalten der Kerne bei der Entwickelung des Embryosacks und die Voränge bei der Befruchtung,"[1] I gave a brief account of karyokinesis in the vegetative cells of *Lilium*. My remarks there are confined largely to the behavior of the chromatin, the formation of the spindle being only incidentally referred to. As regards the latter process, however, it is stated that the kinoplasm is present in a much

[1] Jahrbücher für wiss. Bot., Bd. XXXI, 1897.

smaller quantity than in the sexual cells of the same plant. As a rule it is not at first arranged radially about the nucleus, but forms a delicate weft which may be closely applied to the nuclear membrane. Not infrequently a few radiating kinoplasmic fibres are present in addition to the weft. Frequently, and especially in the earlier stages, this weft is so delicate and equally distributed about the nucleus that the most careful staining is necessary to detect its presence, and that for this reason it may be easily overlooked.

In many cases the fibres of this weft are collected in larger and looser masses at different parts on the nuclear membrane, when the weft is more easily demonstrated. The kinoplasmic fibres of the weft form a multipolar spindle which is rapidly transformed into the typical bipolar type. In the cells of the ovule of *Helleborus* the cap-like masses of kinoplasmic fibres upon diametrically opposite sides of the nucleus is often more readily seen than in *Lilium*.

Recent investigations which tend to confirm the above statement, have shown that these accumulations of kinoplasmic fibres are characteristic of a definite phase in the development of the spindle in certain vegetative cells.

The results recently published by Hof[1], which are in accord with the foregoing statement, have contributed much valuable and additional data to our knowledge of the formation of the karyokinetic spindle in higher plants.

Hof finds further that the anlage of the spindle may be bipolar from the beginning, but in *Vicia faba* and *Pteris* sp. along with this type, the monoaxial multipolar anlage occurs.

Thus no fundamental difference exists between the origin of the spindle in vegetative and reproductive cells of the higher plants, save that in the latter (pollen, and embryosac-mother-cells) the anlage of the spindle is multipolar, with little or no definite indication of the future longitudinal axis, while in the former the bipolar anlage may occur side by side with the multipolar mono-axial type. It may be, therefore, as stated by Hof, that "es ergiebt sich, so scheint mir, aus den bisherigen Untersuchungen, dass ein principieller Unterschied zwischen den multipolaren und bipolaren Anlagen der Kernspindel nicht gegeben ist, beide Vorgänge sind durch die monaxial-multipolaren mit einander vereint."

[1] Hof, A. C.: "Histologische Studien an Vegetationspunkten," Botanisches Centralbl. Bd. LXXVI, 1898.

The development of the karyokinetic spindle as it is now known proves conclusively that centrosomes do not exist in the higher plants.

My own studies, now in progress, confirm my previous statement, and so far as they have extended are not at variance with the results of Hof.

THE CENTROSOME IN DICTYOLA. BY DAVID M. MOTTIER.

[Published in Ber. d. deutsch. Botan. Gesell., Bd. XVI, 1898.]

THE CENTROSOME IN CELLS OF THE GAMETOPHYTE OF MARCHANTIA.
BY DAVID M. MOTTIER.

[Abstract.]

While making preparations to demonstrate to a class the archegonium and its development in *Marchantia polymorpha*, my attention was attracted by conspicuous aggregations on opposite sides of certain nuclei in the stalk cells of the receptacle. Closer observation showed that these aggregations were due to the presence of "centrospheres," about which and among whose radiations were collected chloroplasts and finer cytoplasmic granules.

For our knowledge of centrosomes or "centrospheres" in liverworts, we are indebted largely to the recent researches of Farmer.[1]

"When nuclear division is about to take place," says Farmer, in speaking of the germinating spores in *Pellia epiphylla* Nees, "two structures of a minute size appear on the outside of and in contact with the nuclear wall, and from them beautiful radiations extend. These bodies, or centrospheres, are commonly seen to be diametrically opposite to each other in position, for we have not succeeded in demonstrating them in the perfectly resting cells, nor have we been able to ascertain the existence of any definite particle within them which would indicate the presence of a centrosome. It is true that in some instances such a point could be distinguished, but we do not attach much importance to it, since in the great majority of centrospheres it completely eluded recognition."

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[1] Farmer, J. B., and Reeves, Jesse: "On the Occurrence of Centrospheres in Pellia epiphylla Nees." Ann. Bot., VIII, 219-224, 1894.

Farmer, J. B.: "On Spore-Formation and Nuclear Division in the Hepaticae," Ann. Bot., IX, 469-523, 1895.

Recent researches upon certain brown algae *(Dictyota,*[1] *Stypocaulon*[2] and *Fucus*[3]*)* have shown that the centrosome in plants is in all probability something more than a mere point of insertion of the kinoplasmic radiations. In *Dictyota* there seems to be no doubt but the centrosome is a definite body, being here relatively large and rod-shaped, and from which kinoplasmic fibres radiate. In the vegetative cells of *Marchantia* I can not assert with absolute certainty that a definite central body or centrosome exists in all cases, but I believe that such is the case. In some in which the kinoplasmic radiations are densely stained, the dark center seems to be merely the point of union of the radiations, but if the stain be washed out so that the radiations are almost colorless, a well-defined and densely-stained central body is generally to be seen. Since it is now known that the small hyaline space in which the centrosome is sometimes seen to lie, is an artefact, the term centrosphere at present has reference to the centrosome with its radiations, and it is in this sense that the word is here used. By the time the chromosomes are differentiated, and even earlier, the centrospheres lie nearly diametrically opposite each other, and appear to be in all cases attached to the nuclear membrane. The nucleus is now generally elliptical in shape with rather pointed ends at which the centrosomes are situated. As Farmer states, it does seem that the centrospheres exert a pulling strain upon the nucleus, and I have often found that the ends were prolonged into slender beaks terminating in the centrospheres.

I have not as yet been able to obtain a series of stages illustrating the formation of the spindle. The mature spindle consists of delicate bundles or strands of kinoplasmic fibres extending from pole to pole. The fibres stain readily with gentian violet, so that the spindle although often quite small is not an inconspicuous object even when observed by means of dry lenses.

As soon as the chromosomes are regularly arranged in the equatorial plate, the polar radiations become faint and soon disappear. In some cases no polar radiations were visible at this stage.

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[1] Mottier, D. M.: "Das Centrosom bei Dictyota (Vorläufige Mittheilung)." Ber. der deutsch. bot. Gesellsch., XVI, 1898.

[2] Swingle, W. T.: "Zur Kenntniss der Kern- und Zelltheilung bei den Sphacelariaceen." Jahrb. für wiss. Bot., XXX, 1897.

[3] Strasburger, E.: "Kerntheilung und Befruchtung bei Fucus," Jahrb. für wiss. Bot XXX, 1897.

When the daughter chromosomes have arrived at the poles and before any trace of a nuclear membrane is visible, neither centrosome nor polar radiations are to be seen. Sometimes a small, densely-stained body may be seen lying against the nuclear wall, but since these bodies are precisely like others scattered about in the cytoplasm, it would be mere empiricism to speak of them as centrosomes.

The vegetative cells of the gametophyte of *Marchantia* can not be said to be especially favorable for the study of the karyokinetic process. The nuclei are small and the chloroplasts as a rule collect about the centrospheres, thus obscuring many of the finer details.

Endosperm Haustoria in Lilium Candidum. By David M. Mottier.

[Abstract.]

So far as the writer is aware, there is as yet no case on record in which it is known that a special provision is made by the endosperm of any of the *Liliaceae* for increasing the absorbing surface in the chalazal region.

During a study upon the fecundation in *Lilium candidum*, it was noticed that cells of the developing endosperm bordering upon the chalazal surface were rendered strikingly conspicuous by their denser contents and the presence of karyokinetic figures, and that the sharp and regular line of demarkation between endosperm and the tissue of the ovule almost disappears at the chalaza. Here the endosperm cells send out short, irregular tubes which penetrate the tissue of the chalaza in a way similar to that in which the cells of the foot of the sporophyte in *Anthoceros* become rooted in the tissue of the gametophyte.

The growth of the developing seed is such that, before the endosperm completely fills the cavity of the embryo-sac, the chalazal region is forced into a lateral position with respect to the longer axis of the seed. The chalazal end of the embryo-sac originally occupied by the antipodal cells persists as a small cavity, which is now filled with a few endosperm cells, projecting into the chalazal tissue. A longitduinal section of the endosperm at this stage in development, coincident with the plane of the funiculus, presents, in the chalazal region, a picture recalling that of a longitudinal section through the foot of the sporophyte of *Anthoceros*.

There seems to be no doubt but this behavior of the endosperm in *Lilium candidum* is a provision for increasing the absorbing surface of that tissue in the region of greater food supply. These cells of the endosperm may, therefore, be known as *endosperm haustoria*.

A similar behavior of the epidermal cells in certain parts of the embryo, such as the colyledons, serving as special organs of absorption, is well known, and a few striking illustrations of the same are brought together by Haberlandt in his "Physiologische Pflanzenanatomie."

The narrowed end of the embryo-sac, which extends into the chalazal region in certain *Compositae (Senecio)*, is doubtless associated with a like function. In *Senecio*, however, the antipodal cells not only persist but multiply, while in *Lilium candidum* these disappear early, and the space which they formerly occupied is soon filled by endosperm cells.

THE EFFECT OF CENTRIFUGAL FORCE UPON THE CELL. BY DAVID M. MOTTIER.

[Pub. in Annals of Botany, 1899.]

ABSORPTION OF WATER BY DECORTICATED STEMS. BY G. E. RIPLEY.

It is probably known to all students of botany that the sap in a plant rises chiefly through the wood-cells, and not through the cortex-cells. This can be easily demonstrated by securing two similar leafy shoots from a tree or bush. From one, remove all the cortex for about an inch above the cut end, and from the other the wood for about the same distance. Now place the two prepared ends in water, and observe the rate of wilting as shown by the turgescence of the foliage. In a few hours, if transpiration is rapid, the shoot from which the wood has been removed will begin to wilt, and after a time will lose all turgescence, while the decorticated one will appear almost as fresh as at first and will continue so for a considerable time. This proves that the wood-cells and not the cortex-cells supply the water to the shoot.

Last spring, while performing this experiment in the laboratory of vegetable physiology at Purdue University, it was observed that the third unprepared shoot, used as a control on the other two, wilted much sooner than the decorticated one. This observation at once raised the question

in what way the removal of the cortex at the cut end of a shoot would delay wilting. In the unprepared shoot used the wood-cells in touch with the water were only those exposed by the cross-section of the stem, but in the decorticated one, besides these, the cells from which the cortex had been removed, were also brought in touch with the water, thereby increasing the number of wood-cells in contact with the water in the decorticated shoot. As it has already been shown that the cortex is a poor conductor of water, we can see that it will prevent the water from reaching the wood-cells beneath, but if removed from the shoot the water is brought in contact with these cells the same as with those exposed at the cut end of the shoot, and as results show, is taken up by them.

The turgescence of a shoot depends upon the amount of water supplied to it in relation to the amount given off by transpiration, and this can be prolonged by providing a greater supply of water, or by decreasing the rate of transpiration. As the latter, however, is dependent upon the condition of the atmosphere, it is beyond our control; but the supply of water is not. Pressure can be used to increase this supply to the cut shoot, and by this guttation can be produced in the vigorous shoot, and turgescence can be restored in the wilted. But this is too inconvenient to be of much practical value in preserving cut shoots in fresh condition. If the supply of water to a cut shoot can be increased by removing the cortex from above the cut end, this will give a very simple method for prolonging turgescence, a method that all may employ who are lovers of cut flowers and delight to preserve them as long as possible.

In the experiment mentioned, as the decorticated did not wilt as soon as the corticated shoot, the former must have received more water than the latter. If the end of a cut shoot that is in water be removed at different intervals so that fresh cells are exposed to the water, the shoot will not wilt as soon as it would if the fresh cells were not exposed. This is due to the fact that as the cells take up the water they act as a filter and stop all foreign matter present in the water, and so in time the cells are choked, and can not take up more water. When the cortex is removed more wood-cells are exposed, and it may be that the water is not taken up any faster by the shoot, but on account of the greater surface of cells exposed they do not choke so soon. But if the cells exposed by the cross-section do not overload the carrying capacity of the shoot, it should take up more water when the cortex is removed.

In order to determine if different shoots would give results similar to those observed in the elder shoot used in the experiment mentioned, a number of experiments were carried out last fall. The data, from all but three of these experiments, were very satisfactory and supported the first result.

The three which were not very satisfactory were with the tomato, gladiolus and one of the maples. They will be mentioned later. In these experiments duplicates were carried out with all but the rose, dahlia and gladiolus; but were not carried out at the same time except for two of the experiments. The stems for the duplicates, while of the same species, were not always taken from the same plant from which the first stems were secured. The condition of the stems used was noted, efforts being made to secure the two as near alike as possible. The number and condition of the leaves were taken, but the amount of foliage present did not appear to have any appreciable effect upon the results. If, however, a large surface of foliage was employed and suitable apparatus used, it would undoubtedly be apparent in the data.

The length that the stems were decorticated was measured for each experiment, and the relation between the length of cortex removed and the time of wilting is shown in the table.

In the first of the experiments performed last fall, stems from a catalpa were used. The tree stood in the open on high, dry, gravelly soil, and was about ten inches in diameter. Two stems each having the same number of leaves were secured. From one the cortex was removed for about 2.8 cm. above the cut end, from which, just before it was put in the water, a fresh cross-section was made so as to expose fresh cells to the water. About 3 mm. were cut off so that there was left about 2.5 cm. of decorticated stem. A fresh cross-section was also made on the corticated before it was put in water. Both stems were put in water at the same time, September 20, at 11 a. m., with the air temperature at 18.5°C. The sky was cloudy and transpiration was slow that day, but by 9 a. m. the next day, with a clear sky and the temperature at 22.5°C., the corticated stem had wilted. The decorticated did not wilt until after five that evening. Six days later catalpa stems were tried again. This time the cortex was removed for only 1 cm. The stems, prepared as before, were placed in water at 7 a. m., temperature 21°C. At 4 p. m. that day, temperature 24.5°C., the corticated had wilted, the decorticated wilting about three hours later.

If we compare the data secured from these two experiments, we find that in the first, with 2.5 cm. of cortex removed, there is a difference of over eight hours in the wilting of the corticated and decorticated stem; and in the second, with only 1 cm. of cortex removed, there is a difference of only about three hours. Now, if we take for granted that the two corticated stems, if under same conditions, would have wilted at about the same time, we have in the decorticated stems for a difference of 1.5 cm. of cortex removed about five hours difference in their wilting.

It is not supposed that this will not vary, nor that stems from other plants will give the same data, for different stems take up water at different rates; but the following, maple, oak, aster cordifolius, wild cherry, Indian mallow, rose, bittersweet, dahlia and chrysanthemum, with which two experiments were tried from all but the rose and dahlia, gave a similar relation between the length of cortex removed and the time of wilting.

With some of the experiments wilting was slow on account of so much moisture being present in the atmosphere, while in others it was rapid, due to the absence of moisture. But in no instance was it evident that the decorticated stem wilted sooner than the corticated one, though with the tomato and gladiolus the time was apparently the same.

Aster cordifolius gave the best results. In the first experiment with it the corticated wilted in about forty-five hours; the decorticated, with 1 cm. of cortex removed, wilted in about sixty-four hours. In the duplicate, the corticated wilted in about fifty-six hours; the decorticated, with 2 cm. of cortex removed, wilted in about ninety hours. It was cloudy all the time that these two experiments were being carried on, and part of the time was raining, so that transpiration was slow.

If we compare these two experiments we find that in the first there is nineteen hours' difference in the wilting of corticated stem, and decorticated with 1 cm. of cortex removed, and in the duplicate there is thirty-four hours' difference in the wilting of corticated stem and decorticated with 2 cm. of cortex removed. The data secured from the other experiments, except those mentioned as giving no results, were not so marked as the aster. The data from the rose were furnished by Dr. Arthur. Only one experiment was tried but the result was good, the decorticated being almost as fresh as at first, when the corticated had wilted.

It must be remembered that the results given are only approximate, as the eye had to decide when the stems had wilted. With the use of suitable apparatus we might discover a relation between the time of wilt-

ing and the length of cortex removed. This, if proven, though it might not be of much value in itself, may bring us a step-nearer to the final answer of that great question, How does sap rise in plants?

In the experiments with tomato, gladiolus and one of the maples, no definite results were secured. The tomato stems were very tender and transpiration was so rapid that the stems would wilt in a short time, remain wilted until sundown and then revive only to wilt the next morning. The gladiolus specimens used were secured from a bouquet and were not in a fresh condition, which might account for failure to give results. One of the three maple experiments also gave no difference in time of wilting, but in the evening the decorticated stem revived, while the corticated did not, proving that the former took up water more readily than the latter.

The following table gives the results of the experiments, the average temperature, length of cortex removed, time of wilting of corticated and decorticated, and the difference in time of wilting:

Stems Used.	Length of Stem Decorticated in cm.	Average Temperature in C.	Hours Before Wilting.		Difference in Favor of Decorticated
			Corticated.	Decorticated	
Catalpa	2.5	20.5	22	30+	8+
Duplicate	1.0	22.7	9+	12+	3+
Maple	3.0	21.2	10	36	26
Duplicate	1.5	26.0	20	27.5	7.5
Oak	1.5	29.0	9	13	4
Duplicate	2.0	30.0	7	13.5	6.5
Aster C.	1.0	20.2	45	64	19
Duplicate	2.0	18.9	56	90	34
Wild Cherry	1.5	20.1	15	22	7
Duplicate	2.5	22.0	12+	22	10
Indian Mallow	2.0	24.0	7	11	4
Duplicate	1.0	26.7	8	10	2
Rose	3 (about)	....	40	Still fresh.	....
Bittersweet	2.5	19.0	30	37	7
Duplicate	2.5	21.0	36	41	5
Dahlia	2.0	23.0	30	48	18
Chrysanthemum	3.0	26.5	29	46	17
Duplicate	1.5	24.0	33	39	6

Just in what way the removal of cortex delays wilting in the cut shoot is yet to be determined, but that it does is evident from results secured. It seems reasonable to suppose that if the cortex is removed and more wood-cells exposed, the shoots should take up more water, provided the cells exposed by the cross-section are not able to supply all the stem can carry. If they can, however, then the delay in wilting must depend on the fact that the more wood-cells exposed, the more time required for them to choke and break down; and this leaves us with the problem as regards the "absorption of water by decorticated stems," either the supply is greater or the cells do not choke so soon.

Indiana Plant Rusts, Listed in Accordance with Latest Nomenclature.

By J. C. Arthur.

Stability in nomenclature is conceded by all to be important. In botany there should be one recorded name for each plant by which it can be identified, and none other should be valid. If this could be strictly maintained, the study of plants would be simplified, for not only would doubt be removed regarding the true application of a name, but when a name was once learned it would hold good for all time. How different the present status of botanical usage is has been brought to the attention of every one using the successive editions of Gray's Manual, a work that probably has introduced more American students of recent years to an acquaintance with the plants of field and highway than all others combined. Those of us who were brought up botanically on the fifth edition learned to call the pretty little white rue-anemone, so abundant in spring, *Thalictrum anemonoides*, but with the new edition in 1890 we were asked to forget that name—no, not to forget it, but to remember that it is not the right one—and to say, instead, *Anemonella thalictroides*. If one had but to relearn a few hundred names, and feel assured that no further demands would be thrust upon him, the task would seem less wearisome. But the new manual names are scarcely fixed in mind before the valuable work by Britton and Brown comes to us, a work so admirably conceived and executed, and so conveniently devised to assist the learner, that it must be recognized as the foremost manual of our flora, and we are again asked to put away the former names of our little rue-anemone and to rechristen it among our list of acquaintances as *Syndesmon thalictroides*. There are

many such instances; for example, the Canada thistle is changed from *Cirsium arvensis* to *Cnicus arvense*, and again to *Carduus arvensis*. If we should include the earlier editions of Gray's Manual, and also the works of other authors, the number of synonyms would be greatly increased, some plants, in fact, having as many as a score of Latin names. If we add to this the not infrequent application of the same name to two or more distinct kinds, the confusion becomes appalling.

All this unfortunate state of affairs in the botanical camp has been recognized for a long time, and various measures have been proposed from time to time, and more or less effectively applied, to bring about a reform. Of these efforts the most prominent are the DeCandolle principles of 1813, the Paris code of 1867, the ruling of the Genoa Congress of 1892, and the Rochester-Madison code of 1892-3. All the clearly defined measures are essentially in accord in recognizing as fundamental the statement made by DeCandolle (1813) in his Elements of Botany (p. 228), viz.: "In order that a nomenclature become universal it must be fixed, and the fixity of that of natural history is founded on this principle, that the first one who discovers an object, or who records it in the catalogue of science, has the right to give it a name, and that this name must be necessarily accepted, unless it already belongs to another object or transgresses the essential rules of nomenclature." The application of this principle of recognizing the first name applied to a plant as its only legitimate and correct name is known as the law of priority. But to disentangle the confusion of a hundred and fifty years or more since Linnæus established binomial nomenclature is a great task, and to promulgate unequivocal rules for the present and future naming of plants is almost equally difficult.

The first bomb that was fired so effectively that the botanical camp was stirred to its center and forced to become aggressive, may be said to be the publication in 1891 of Otto Kuntze's *Revisio generum plantarum*. This work discarded names in general use by the hundreds, almost by thousands, and substituted unfamiliar ones, on the ground of rigid priority. It was like an earthquake shaking the whole structure of the nomenclatorial palace, and threatening no end of disaster. But those who believe that the sooner the inevitable change from a policy of inaction to a fearless reconstruction is made have welcomed the efforts of Dr. Kuntze, and have set about to see in how far he is right and to aid as much as possible in establishing nomenclature upon a firm basis.

The class of plants to which I wish to call attention in this connection, the fungi, was not included in Dr. Kuntze's publication of 1891; but in a recent supplemental volume he has taken it up; and it is because some startling changes are proposed among the genera of rusts, a group of plants with which I have lately been working, that it occurred to me that the members of this Academy might be interested in seeing how the list of plant rusts (*Uredineæ*), which have been published from time to time in its Proceedings since 1893, would look when revised in accordance with what appears to be a rigid application of the law of priority. The time at my disposal has not permitted a thorough re-examination of the nomenclatorial history of every species of the list, yet such work as has been done appears to necessitate some changes, which in part were not contemplated by Dr. Kuntze. Some of these changes have been required in order to make the list conform to the Rochester-Madison code, especially in recognizing 1753 as the limit for priority, instead of 1737, as advocated by Dr. Kuntze, and in permitting specific names of any number of syllables, instead of limiting them to eight syllables. It has also been necessary to revive the genus name *Aregma*, established by Fries (*Obs. Myc.*, p. 225) in 1815, to replace the more familiar name of *Phragmidium*, published by Link in 1816.

The plant rusts of our region fall into two principal groups—the *Melampsoraceæ* and the *Pucciniaceæ*. The four genera of the first group are not affected by Dr. Kuntze's researches, but three of the seven genera of the second group are altered, and these are much the largest genera of all the *Uredineæ*. They are *Puccinia*, which is changed to *Dicæoma; Uromyces*, changed to *Cæomurus* and *Gymnosporangium*, which unfortunately is to be known as *Puccinia*. By these changes sixty-nine species of rusts belonging to the Indiana flora, out of a total of eighty species native to the State, are provided with unfamiliar names.

Puccinia first appears as a genus, subsequent to the priority limit of 1753, in a work published by Adanson in 1763, being adopted from a much earlier work by Micheli, who founded it to receive the common European Juniper rust, now called *Gymnosporangium juniperinum*.* Other authors,

*Since the manuscript of this paper went to the printer the correctness of Dr. Kuntze's interpretation of the generic use of *Puccinia* has been called in question by Professor Magnus, with Dr. Kuntze's subsequent approval. But the criticism does not apply, it seems to me, when 1753 is accepted as the limit of priority, instead of 1737, as held by the German writers.

in particular Willdenow, Gmelin, Schmidel and Persoon, added new species to the genus, and especially such rusts as had teleutospores of a similar shape, whether having one, two or many cells. These additions so overshadowed the original Juniper rust and its allies that the genus came to stand for these more abundant and more characteristic rusts. After a time there were gradually separated the one-celled forms, as *Cæomurus*, almost at once changed to *Uromyces*, the many-celled forms, as *Phragmidium*, and the forms with a gelatinous spore-bed, as *Gymnosporangium*, leaving the common two-celled forms under the old name *Puccinia*. We are now asked to restore the name *Puccinia* to its original use, although its misuse has extended over a full century.

The generic name of *Dicæoma*, which was first distinctively applied to the ordinary two-celled forms, appears to have been introduced by Nees von Esenbeck in 1816 as the name of a section, and was erected into a distinct genus by S. F. Gray in 1821. But it never came into general use, and soon disappeared from current books entirely. Of the rusts usually listed under *Puccinia*, there are forty-seven species in the Indiana flora, which are now to be transferred to *Dicæoma*.

The case of the third genus, *Uromyces*, embracing the one-celled rusts, is simpler but quite as annoying. The genus was named by Link in 1809; but not finding the name to his liking, he rechristened the genus seven years afterward, and now after all these years we are called upon to readopt the earlier name, dropping the name *Uromyces*, and to transfer our species to *Cæomurus*. For it was held by DeCandolle long ago that "an author, who has first established a name, has himself no more right than any one else to change it for the simple reason of impropriety," and recent rulings have held the opinion to be sound.

So it comes about that the names of the four largest genera of rusts must be changed, to make them conform to the law of priority, after having been in use almost from the first, and one of these changes is a transfer, which necessarily will cause some subsequent confusion. There appears but one question yet to be answered. We must know whether a thorough inspection of the literature will substantiate the claim that these are in fact the genuine first names for the genera. Feeling considerable confidence in the present conclusion, I here rewrite the Indiana list of *Uredineæ*, to more clearly call attention to the proposed and doubtless inevitable changes.

In the following list the name of the rust which is considered to be the correct first name is printed in small capitals, and when thought necessary for identification is followed by the name that is in more general use printed in italics. The names of the hosts on which the rust grows are given for each species, conforming to the nomenclature of Britton and Brown's "Illustrated Flora of the Northern States and Canada," with the more familiar name added in parenthesis, when a difference occurs. The references after each host are to the page and year of the Proceedings of the Academy, where additional information can be found. Both genera and species are arranged alphabetically.

The list does not include the unattached forms under the genera *Æcidium* and *Uredo*, of which there are about twenty kinds recorded for Indiana. Careful observation supplemented by cultures must finally decide where these belong. The only additions here made to the previous records for the State consist of a few host plants, which are clearly indicated. The species included by Miss Lillian Snyder in her paper before the present session of the Academy could not of necessity be cited.

MELAMPSORACEÆ.

1. CHRYSOMYXA ALBIDA *Kühn.* (*Coleosporium Rubi E. & H.*)
   On Rubus cuneifolius Pursh. 1893:50.
   On Rubus villosus Ait. 1893:50.

2. COLEOSPORIUM HYDRANGEÆ (*B. & C.*). (*Uredo Hydrangeæ* B. & C.)
   On Hydrangea arborescens L. 1893:56. 1896:218.

3. COLEOSPORIUM IPOMŒÆ (*Schw.*) *Bur.*
   On Ipomœa pandurata (L.) Mey. 1896:171, 218.

4. COLEOSPORIUM SOLIDAGINIS (*Schw.*) *Thuem.*
   On Aster azureus Lindl. 1893:50.
   On Aster cordifolius L. 1893:51.
   On Aster Novæ-Angliæ L. 1893:51.
   On Aster paniculatus Lam. 1893:51.
   On Aster puniceus L. 1893:51.
   On Aster sagittifolius Willd. 1893:51.
   On Aster salicifolius Lam. 1893:51.
   On Aster Shortii Hook. 1893:51.

On Aster Tradescanti L. 1893:51.

On Solidago arguta Ait. 1893:51.

On Solidago cæsia L. 1893:51.

On Solidago Canadensis L. 1893:51.

On Solidago flexicaulis L. (*S. latifolia* L.) 1893:51.

On Solidago patula Muhl. 1893:51.

On Solidago rugosa Mill. 1893:51.

On Solidago serotina Ait. 1893:51.

5. Coleosporium Vernoniæ *B. & C.*

On Vernonia fasciculata Michx. 1893:51.

On Vernonia Noveboracensis (L.) Willd. 1893:51.

6. Melampsora populina (*Jacq.*) *Lev.*

On Populus balsamifera L. 1893:51.

On Populus deltoides Marsh. (*P. monilifera* Ait.) 1893:51. 1896:218.

On Populus grandidentata Michx. 1893:51.

On Populus tremuloides Michx. 1893:51.

7. Melampsora farinosa (*Pers.*) *Schrœt.*

On Salix cordata Muhl. 1893:51.

On Salix discolor Muhl. 1893:51. 1896:218.

On Salix fluviatilis Nutt. (*S. longifolia* Muhl.) 1893:52.

On Salix nigra Marsh. 1893:51.

8. Pucciniastrum Agrimoniæ (*DC.*) *Diet.* (*Caeoma Agrimoniæ* Schw.)

On Agrimonia hirsuta (Muhl.) Bick. (*A. Eupatoria* Am. Auct.) 1893:50. 1896:218.

On Agrimonia parviflora Sol. 1893:50.

PUCCINIACEÆ.

9. Aregma disciflora (*Tode*) *nom. nov.* (*Phragmidium subcorticium* Wint.)

On Rosa Carolina L. 1893:52.

On Rosa humilis Marsh. (*R. lucida* Am. Auct.) 1893:52.

On Rosa setigera Michx. 1893:52.

10. Aregma Fragariæ (*DC.*) *nom. nov.*

On Potentilla Canadensis L. 1893:52. 1896:218.

11. Aregma speciosa *Fr.* (*Phragmidium speciosum* Cke.)

On Rosa Carolina L. 1896:219.

On Rosa humilis Marsh. Tippecanoe Co., 5, 1898 (*Arthur*).

12. CÆOMURUS CALADII (*Schw.*) *Kuntze.* (*Uromyces Caladii* Farl.)
On Arisæma triphyllum (L.) Torr. 1893 : 56. 1896 : 222.
On Arisæma Dracontium (L.) Schott. 1893 : 56. 1896 : 222.

13. CÆOMURUS CARYOPHYLLINUS (*Schr.*) *Kuntze.*
On Dianthus Caryophyllus L. 1893 : 56.

14. CÆOMURUS EUPHORBIÆ (*Schw.*) *Kuntze.*
On Euphorbia dentata Michx. 1893 : 57. 1896 : 222.
On Euphorbia nutans Lag. (*E. hypericifolia* Gr.) 1893 : 57. 1896 : 222.

15. CÆOMURUS GAURINUS (*Pk.*) *nom. nov.* (*Uredo gaurina* (Pk.) DeT.)
On Gaura biennis L. 1896 : 222.

16. CÆOMURUS GRAMINICOLUS (*Burr.*) *Kuntze.*
On Panicum virgatum L. 1893 : 57.

17. CÆOMURUS HOWEI (*Pk.*) *Kuntze.*
On Asclepias incarnata L. 1893 : 57. 1896 : 222.
On Asclepias purpurascens L. 1893 : 57.
On Asclepias Syriaca L. (*A. Cornuti* Dec.) 1893 : 57. 1896 : 222.

18. CÆOMURUS HEDYSARI-PANICULATI (*Schw.*) *nom. nov.*
On Meibomia Canadensis (L.) Kuntze (*Desmodium C.*) 1896 : 222.
On Meibomia canescens (L.) Kuntze (*Desmodium c.*) 1893 : 57.
On Meibomia Dillenii (Darl.) Kuntze (*Desmodium D.*) 1893 : 57. 1896 : 222.
On Meibomia lævigata (Nutt.) Kuntze (*Desmodium l.*) 1893 : 57.
On Meibomia paniculata (L.) Kuntze (*Desmodium p.*) 1893 : 57.
On Meibomia viridiflora (L.) Kuntze (*Desmodium v.*) 1893 : 57.

19. CÆOMURUS HYPERICI-FRONDOSI (*Schw.*) *nom. nov.*
On Hypericum Canadense L. 1893 : 57.
On Hypericum mutilum L. 1893 : 57.
On Triadenum Virginicum (L.) Raf. (*Elodea campanulata* Marsh.) 1893 : 57.

20. CÆOMURUS JUNCI (*Schw.*) *Kuntze.*
On Juncus tenuis Willd. 1896 : 222.

21. CÆOMURUS LESPEDEZÆ-PROCUMBENTIS (*Schw.*) *nom. nov.*
On Lespedeza frutescens (L.) Brit. (*L. reticulata* Pers.). 1893 : 57.
On Lespedeza procumbens Michx. 1893 : 57.
On Lespedeza repens (L.) Bart. 1896 : 222.

22. CÆOMURUS PERIGYNIUS (*Halst.*) *Kuntze.*
On Carex pubescens Willd. 1893 : 57.

23. Cæomurus Phaseoli (*Pers.*) *nom. nov.*
On Strophostyles helvola (L.) Brit. (*Phaseolus diversifolius* Pers.). 1893:56. 1896:172, 222.

24. Cæomurus Pisi (*Pers.*) *Gray.*
On Vicia Americana Muhl. 1896:222.

25. Cæomurus Polygoni (*Pers.*) *Kuntze.*
On Polygonum aviculare L. 1893:57. 1896:223.
On Polygonum erectum L. 1893:58.

26. Cæomurus Rudbeckiæ (*Arth. & Holw.*) *Kuntze.*
On Rudbeckia laciniata L. 1894:152.

27. Cæomurus Terebinthi (*DC.*) *Kuntze.*
On Rhus radicans L. (*R. Toxicodendron* Am. Auct.). 1893:58.

28. Cæomurus Trifolii (*Hedw.*) *Gray.*
On Trifolium hybridum L. 1893:58.
On Trifolium medium L. 1893:58.
On Trifolium pratense L. 1893:58. 1896:223.
On Trifolium repens L. 1893:58.

29. Dicæoma Andropogi (*Schw.*) *Kuntze* (*Puccinia Andropogi* Schw.).
On Andropogon furcatus Muhl. 1896:219.
On Andropogon scoparius Michx. 1896:219.

30. Dicæoma Anemones (*Pult.*) *nom. nov.* (*Puccinia fusca* Relh.).
On Anemone quinquefolia L. (*A. nemorosa* Mx.). 1894:151.

31. Dicæoma Anemones-Virginianæ (*Schw.*) *nom. nov.* (*Puccinia solida* Schw.).
On Anemone cylindrica Gr. 1896:219.

32. Dicæoma angustatum (*Pk.*) *Kuntze.*
On Scirpus atrovirens Muhl. 1893:52. 1896:219.
On Scirpus cyperinus (L.) Kunth. 1893:52.

33. Dicæoma apocryptum (*E. & Tr.*) *Kuntze.*
On Hystrix Hystrix (L.) Millsp. 1893:52.

34. Dicæoma argentatum (*Schultz*) *Kuntze.*
On Impatiens biflora Walt. (*I. fulva* Nutt). 1893:52. 1896:220.

35. Dicæoma Asperifolii (*Pers.*) *Kuntze* (*Puccinia Rubigo-vera* (DC.) Wint.).
On Avena sativa L. 1893:55.
On Elymus Virginicus L. 1893:55. 1896:221.
On Secale cereale L. 1896:221.

36. Dicæoma asteris (*Duby*) *Kuntze.*
On Aster cordifolius L. 1893:52.
On Aster lateriflorus (L.) Brit. (*A. diffusus* Ait.). 1896:219.
On Aster paniculatus Lam. 1893:52.

37. Dicæoma Bolleyanum (*Sacc.*) *Kuntze.*
On Carex sp. 1893:52. 1896:219.

38. Dicæoma Circææ (*Pers.*) *Kuntze.*
On Circæa Lutetiana L. 1893:53. 1896:219.

39. Dicæoma Convolvuli (*Pers.*) *Kuntze.*
On Convolvulus sepium L. 1893:53. 1896:219.

40. Dicæoma Cyperi (*Arth.*) *Kuntze* (*Puccinia nigrovelata* E. & T. and *P. indusiata* D. & H).
On Cyperus strigosus L. 1893:53, 54. 1894:154, 157. 1896:219, 220.

41. Dicæoma Dayi (*Clint.*) *Kuntze.*
On Steironema ciliatum (L.) Raf. 1893:53.

42. Dicæoma dochmia (*B. & C.*) *Kuntze.*
On Muhlenbergia diffusa Schreb. 1893:53, 55.
On Muhlenbergia sylvatica Torr. 1896:221.

43. Dicæoma Eleocharidis (*Arth.*) *Kuntze.*
On Eleocharis palustris (L.) R. & S. 1893:53. 1896:219.

44. Dicæoma emaculatum (*Schw.*) *Kuntze.*
On Panicum capillare L. 1893:53. 1896:220.

45. Dicæoma epiphyllum (*L.*) *Kuntze* (*Puccinia Poarum* Niels.).
On Poa pratensis L. 1893:57.

46. Dicæoma flosculosorum (*A. & S.*) *Martius.*
On Carduus lanceolatus L. 1893:53.
On Taraxacum Taraxacum (L.) Karst. 1893:53. 1896:219.

47. Dicæoma galiorum (*Lk.*) *nom. nov.*
On Galium Aparine L. 1896:172.
On Galium asprellum Michx. 1893:53.
On Galium concinnum T. & G. 1893:53.
On Galium triflorum Michx. 1893:53.

48. Dicæoma Helianthi (*Schw.*) *Kuntze.*
On Helianthus annuus L. 1893:55.

On Helianthus divaricatus L. 1893:55.
On Helianthus grosse-serratus Mart. 1893:55. 1896:221.
On Helianthus strumosus L. 1893:55.
On Helianthus tracheliifolius Mill. 1893:55.

49. DICÆOMA HELIOPSIDIS (*Schw.*) *Kuntze.*
On Heliopsis scabra Dunal. 1893:54.

50. DICÆOMA KUHNIÆ (*Schw.*) *Kuntze.*
On Kuhnia eupatorioides L. 1893:54. 1896:220.

51. DICÆOMA LATERIPES (*B. & R.*) *Kuntze.*
On Ruellia strepens L. 1893:54. 1896:218.

52. DICÆOMA LOBELIÆ (*Ger.*) *nom. nov.*
On Lobelia syphilitica L. 1893:54. 1896:220.

53. DICÆOMA LUDIBUNDUM (*E. & E.*) *Kuntze.*
On Carex sparganioides Muhl. 1896:220.

54. DICÆOMA MENTHÆ (*Pers.*) *Gray.*
On Blephilia hirsuta (Pursh.) Torr. 1893:54. 1896:220.
On Cunila origanoides (L.) Brit. 1893:54.
On Mentha Canadensis L. 1893:54.
On Monarda fistulosa L. 1893:54. 1896:220.
On Koellia pilosa (Nutt.) Brit. 1893:54.
On Koellia Virginiana (L.) MacM. 1893:54. 1896:220.

55. DICÆOMA OBTECTUM (*Pk.*) *Kuntze.*
On Scirpus lacustris L. 1894:151.

56. DICÆOMA PHYSOSTEGIÆ (*P. & C.*) *Kuntze.*
On Physostegia Virginiana (L.) Benth. 1894:151. 1896:220.

57. DICÆOMA POCULIFORME (*Jacq.*) *Kuntze* (*Puccinia graminis* Pers. and *Æcidium Berberidis* Pers.).
On Agrostis sp. 1893:53.
On Avena sativa L. 1893:53. 1896:220.
On Berberis vulgaris L. 1893:49.
On Dactylis glomerata L. 1896:220, 223.
On Hordeum jubatum L. 1896:220, 224.
On Poa compressa L. 1893:53.
On Poa pratensis L. 1893:53.
On Triticum vulgare L. 1893:54.

58. DICÆOMA PODOPHYLLI (*Schw.*) *Kuntze.*
On Podophyllum peltatum L. 1893:54. 1896:221.

59. DICÆOMA POLYGONI-AMPHIBII (*Pers.*) *nom. nov.**
On Polygonum emersum (Mx.) Brit. (*P. Muhlenbergii* Wats.). 1893:55.
On Polygonum hydropiperoides Michx. Tippecanoe Co., 10, 1898 (*Stuart*).
On Polygonum lapathifolium L. Tippecanoe Co., 10, 1898 (*Arthur*).
On Polygonum Pennsylvanicum L. Tippecanoe Co., 10, 1898 (*Arthur*).
On Polygonum punctatum Ell. (*P. acre* H. B. K.). 1893:55, 57.

60. DICÆOMA POLYGONI-CONVOLVULI (*Hedw.*) *nom. nov.*
On Polygonum Convolvulus L. Tippecanoe Co., 10, 1898 (*Arthur*).
On Polygonum scandens L. 1896:223.

61. DICÆOMA PRENANTHIS (*Pers.*) *Kuntze.*
On Nabalus albus (L.) Hook. 1893:55. 1896:221.

62. DICÆOMA RANUNCULI (*Seym.*) *Kuntze.*
On Ranunculus septentrionalis Poir. 1893:55.

63. DICÆOMA RHAMNI (*Gmel.*) *Kuntze* (*Puccinia coronata* Cda. and *Æcidium Rhamni* Gmel.).
On Avena sativa L. 1896:219.
On Calamagrostis Canadensis (Mx.) Beauv. 1893:53.
On Rhamnus lanceolata Pursh. Tippecanoe Co., 5, 1897 (*Arthur*).

64. DICÆOMA SANICULÆ (*Grev.*) *Kuntze.*
On Sanicula Canadensis L. 1893:55.

65. DICÆOMA SILPHI (*Schw.*) *Kuntze.*
On Silphium sp. 1893:55.

66. DICÆOMA SORGHI (*Schw.*) *Kuntze.*
On Zea Mays L. 1893:54.

67. DICÆOMA TENUE (*Burr.*) *Kuntze.*
On Eupatorium ageratoides L. 1893:55. 1896:221.

68. DICÆOMA THALICTRI (*Chev.*) *Kuntze.*
On Thalictrum dioicum L. 1893:55.

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* Teleutospores have been seen only on the first host named. The other four hosts show an abundance of uredospores, but the lack of teleutospores leaves the correctness of the determination somewhat in doubt.

69. Dicæoma Urticæ (*Schum.*) *Kuntze** (*Puccinia Caricis* Reb. and *Æcidium Urticæ* Schum.)

On Carex bullata Schk. 1893:52.

On Carex Frankii Kunth. (*C. stenolepis* Torr.) 1893:55.

On Carex fœnea Willd. 1893:52.

On Carex lurida Wahl. 1893:52.

On Carex Pennsylvanica Lam. 1896:172.

On Carex straminea Willd. 1893:52.

On Carex virescens Muhl. 1893:52.

On Dulichium arundinaceum (L.) Brit. 1893:52.

On Urtica gracilis Ait. Tippecanoe Co., 5, 1897 (*Arthur*).

70. Dicæoma Vernoniæ (*Schw.*) *Kuntze.*

On Vernonia fasciculata Michx. 1893:55.

71. Dicæoma Vilfæ (*A. & H.*) *nom. nov.*

On Sporobolus asper (Mx.) Kunth. 1896:221.

72. Dicæoma Violæ (*Schum.*) *Kuntze.*

On Viola obliqua Hill (*V. cucullata* Ait.) 1893:56.

On Viola striata Ait. 1893:56.

73. Dicæoma vulpinoidis (*D. & H.*) *Kuntze.*

On Carex vulpinoidea Michx. 1893:56. 1896:221.

74. Dicæoma Windsoriæ (*Schw.*) *Kuntze.*

On Sieglingia seslerioides (Mx.) Scrib. (*Triodia cuprea* Jacq.). 1894:154. 1896:221.

75. Dicæoma Xanthii (*Schw.*) *Kuntze.*

On Ambrosia trifida L. 1893:56. 1896:222.

On Xanthium Canadense Mill. 1893:56. 1896:222.

On Xanthium strumarium L. 1893:56.

76. Gymnoconia interstitialis (*Schl.*) *Lagh.* (*Puccinia Peckiana* Howe and *Æcidium nitens* Schw.).

On Rubus occidentalis L. 1893:54.

On Rubus villosus Ait. 1893:54. 1896:220.

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*This name is made to cover more than one species, but the different forms can not be separated without more study than it is possible to give at the present time. The form on *Carex Frankii*, which has been erroneously referred to *Puccinia Schroeteriana* P. & M., is especially distinct, and probably an undescribed species. Part of this material, however, is without doubt correctly referred as above.

77. Pileolaria brevipes *B. & Br.*

On Rhus radicans L. (*R. Toxicodendron* Am. Auct.) 1893 : 58. 1896 : 223.

78. Puccinia globosum (*Farl.*) *Kuntze* (*Gymnosporangium* Farl. and *Rœstelia lacerata* Fr.).

On Cratægus coccinia L. 1893 : 56.

On Cratægus Crus-Galli L. 1894 : 153.

On Cratægus mollis (T. & G.) Scheele (*C. subrillosa* T. & G.). Tippecanoe Co., 7, 1898 (*Arthur*).

On Cratægus punctata Jacq. 1893 : 56.

On Juniperus Virginiana L. 1893 : 51.

79. Puccinia Juniperi-Virginianæ (*Schw.*) *nom. nov.* (*Gymnosporangium macropus* Lk. and *Rœstelia pyrata* Thax.).

On Malus coronaria (L.) Mill. (*Pyrus coronaria* L.) 1893 : 56. 1896 : 218.

On Malus Malus (L.) Brit. (*Pyrus Malus* L.) Floyd Co., 8, 1890 (*Latta*).

On Pyrus communis L. 1893 : 56.

On Juniperus Virginiana L. 1893 : 51. 1896 : 218.

80. Uropyxis Amorphæ (*Curt.*) *Schroet.*

On Amorpha canescens Pursh. 1893 : 58.

The Uredineæ of Madison and Noble Counties, with Additional Specimens from Tippecanoe County. By Lillian Snyder.

In preceding papers over a hundred species of *Uredineæ* have been reported from the State. Various counties are represented. The largest collection is reported from Tippecanoe, Montgomery and Putnam, while there are a number of counties from which no report has been made. Among the latter are Noble and Madison.

During my collecting in Madison county I have found nine species. Most of these are abundant. Several rusts on leaves of *Carices* were collected, but, with the exception of one, they are not listed here because the hosts have not been determined. The one species on *Carex* given, is classed as *Puccinia carices*, though somewhat different from typical specimens of that species.

The following is a list of the Madison county *Uredineæ*: Following the name of the host is the collector's name, and the date of collection.

Coleosporium sonchi-arvensis (Per.) Lév.

Common on dry ground. Reported from Montgomery, Johnson and Putnam counties in 1893, and from Tippecanoe county in 1896.

On *Aster sp.* 9, 1898 (Snyder).

Melampsora salicina Lév.

Very abundant. Reported from Montgomery, Johnson and Putnam counties in 1893, and from Tippecanoe county in 1896.

On *Salix sp.* 9, 1898 (Snyder).

Puccinia carices (Schum.) Wint.

Very abundant in places. Grows in marshy ground in creek bottom. Reported from Johnson, Montgomery, Putnam, Fulton and Boone counties in 1893, and from Tippecanoe county in 1896.

On *Carex Frankii.* 9, 1898 (Snyder).

Puccinia asteris Duby.

Found only on one species of *aster.* Reported from Montgomery and Tippecanoe counties in 1893.

On *Aster sp.* 9, 1898 (Snyder).

Uromyces Rudbeckii Arth. and Holw.

Abundant. Grows in low, swampy ground. Reported from Montgomery county in 1894.

On *Rudbeckia laciniata* 10, 1898 (Snyder).

Uromyces junci (Schw.) Tul.

Very common in low, black soil. Reported from Tippecanoe county in 1896.

On *Juncus tenuis* 9, 1898 (Snyder.)

Uromyces euphorbiæ C. P.

Common in open fields and along the streets in town. Reported from Putnam, Johnson and Tippecanoe counties in 1893.

On *Euphorbia hypercifolia,* 9, 1898 (Snyder).

Uromyces Howei Peck.

Common. Reported from Johnson, Montgomery, Putnam, Wabash and Dearborn counties in 1893, and Tippecanoe in 1896.

On *Asclepias cornuti* 9, 1898 (Snyder).

Uromyces trifolii (A. and S.) Wint.

Rare. Found in only a very few places in open fields. Reported from Johnson, Montgomery, Putnam, Tippecanoe and Wabash counties in 1893.

On *Trifolium pratense* 11, 1898 (Snyder.)

Besides the Madison county collection, I have in my herbarium fourteen species of *Uredineæ* collected in Noble county by Mr. A. H. King, of Avilla, Ind. In this collection the host of *Puccinia polygoni-amphibii* is new to the State.

Æcidium geranii D. C.

Reported from Vigo county in 1893, and from Tippecanoe in 1896.

On *Geranium maculatum* 5, 1897 (King).

Æcidium grossulariæ D. C.

Reported from Putnam and Montgomery counties in 1893.

On *Ribes cynosbati* 5, 1897 (King).

Cæoma nitens Schw.

First report from the State.

On *Rubus villosus* 5, 1897 (King).

Melampsora populina Lév.

Reported from Montgomery, Putnam, Johnson, Tippecanoe and Marshall counties in 1893.

On *Populus tremuloides* 10, 1897 (King).

Melampsora salicina Lév.

Reported from Montgomery, Johnson and Putnam counties in 1893 and from Tippecanoe in 1896.

On *Salix sp.* 10, 1897 (King).

Roestilia lacerata (Sow.) Fr.

Reported from Montgomery and Putnam counties in 1893 and from Tippecanoe in 1896.

On *Crataegus subvillosa* 6, 1897 (King).

Puccinia maydis Carr.

Reported from Putnam, Montgomery and Dearborn counties in 1893. Not since reported.

On *Zea Mays* 9, 1897 (King).

Puccinia graminis Pers.

Reported from Putnam, Montgomery, Tippecanoe, Marshall and Johnson counties in 1893.

On *Triticum vulgare* 7, 1897 (King).

Puccinia flosculosorum (A. and S.) Wint.

Reported from Marion, Marshall, Putnam, Johnson, Montgomery and Tippecanoe counties in 1893.

On *Taraxacum dens-leonis* 7, 1897 (King).

Puccinia coronata Corda.

Reported from Tippecanoe county in 1893.

On *Avena sativa* 7, 1897 (King).

Puccinia Polygoni-amphibii Per.

Reported from Johnson and Putnam counties in 1893 on *Polygonium acre*, from Fulton and Wabash counties in 1893 on *Polygonium Muhlenbergii*, and from Tippecanoe in 1896 on *Polygonium erectum*.

On *Polygonium hydropiperiodes* 10, 1897 (King).

Puccinia podophylli Schw.

Reported from Johnson, Monroe, Brown, Owen, Vigo, Putnam, Montgomery, Wabash and Dearborn counties in 1893, and from Tippecanoe in 1896.

On *Podophyllum peltatum* 5, 1897 (King).

Uromyces caladii (Schw.) Farlow.

Reported from Vigo, Brown, Montgomery, Putnam, Monroe and Owen counties in 1893, and from Tippecanoe in 1896.

On *Arisæma triphyllum* 5, 1897 (King).

Uromyces trifolii (A. and S.) Wint.

Reported from Johnson, Montgomery, Putnam, Tippecanoe and Wabash counties in 1893.

On *Trifolium pratense* 10, 1897 (King).

The list of additional species to Tippecanoe county is small, only two new species having been found.

Æcidium Lycopi Gerard.

This species was found in swampy ground, and was quite abundant. The leaves and stems of the plant are covered with the *Æcidium* which eats holes in the leaves and destroys the host to some extent.

On *Lycopus sinuatis* 6, 1898 (Snyder).

Puccinia poarum Niels.

Found abundantly in lawns.

On *Poa pratensis* 5, 1897 (Snyder).

ASPERGILLUS ORYZAE (AHLBURG) COHN. BY KATHERINE E. GOLDEN.

A. oryzae is a mould which is of much practical interest by reason of its zymotic activity, since it secretes a diastatic ferment, and also for the claim which has been made that under certain conditions of growth, it is convertible into a yeast, and that, like most yeasts, it can give rise to alcoholic fermentation. It would constitute, in fact, if all claims made

for it were true, a good working basis for an entire distillery. It has been used by the Japanese for centuries in one of their important fermentation industries, that of saké brewing, though like many other ferments used in early times, its true nature was not understood.

In the manufacture of saké, rice is steamed and then mixed with some rice which is covered with the mould, or else the rice is sown with the spores. The spores germinate in the moist and warm air, forming a much-branched mycelium which penetrates to all parts of the grains. This mycelium in developing secretes a diastatic ferment, which acts on the starch, first liquefying it, then changing the liquefied starch to sugar. The formation of spores is avoided by adding quantities of fresh grain from time to time, and mixing the fresh grain with that which has been inoculated. The addition of fresh grain is repeated several times, the mass thus formed of grains and mould being given the name "taka koji." The koji is mashed with about three times its volume of fresh steamed rice and four times its volume of water, and then allowed to stand at a temperature between 20° and 30°C. After some days the mash clears, from the saccharification of the starch, and a spontaneous fermentation sets in. This fermentation is due, however, to a different organism from A. oryzae. It is presumably on account of this fermentation that the mould has been erroneously called Japanese yeast. The fermentation goes on for two or three weeks, and at the end of that time the liquid is filtered. The resulting liquor is clear, pale yellow, and contains about thirteen per cent of alcohol.

The mould has not been well known in this country until recently, though it has been known in Europe, and has received considerable attention from European botanists for about twenty years. In later years very enthusiastic claims have been made in regard to its physiological action, it being claimed that in the growth of the mould, "crystals" of diastase were formed on the filaments, that it was also so active and certain in its action as an alcoholic ferment, that in time it would entirely supersede yeast in the fermentation industries.

HISTORICAL.

The work of the first investigator, Ahlburg, in 1876, was the naming and description of the fungus. He called it Eurotium oryzae, because, as he said, the spores did not form chains, and the mycelium was not bent at angles. He described the sporangium as of a yellow color and possessing

radiating spore tubes, and later on, in 1878, called attention to unimportant characteristics of the mycelium, thus indicating that he was uncertain in regard to the systematic importance of the various parts. He gave no illustrations, so that it was difficult to tell what he meant. In consequence of this, and that he named the fungus Eurotium, some of the later botanists interpreted the sporangia to be perithecia, and the radiating spore tubes asci.

Cohn, in 1883, in treating of the mould as an industrial factor in the manufacture of rice wine, speaks of it as A. oryzae, though he gives no morphological characteristics. Büsgen, in 1885, treats of the size and appearance of the mycelium, conidiophores, sterigmata, and conidia, though not very fully, as these were secondary considerations in his work. He also speaks of its resemblance to A. flavescens. Büsgen was the first to give a detailed description of the mould so that it was possible to compare it with other members of the genus. In 1893, Wehmer took up the work with the idea of making a detailed examination of the structure, and while he was thus engaged, Schröter's work in the same line appeared. Wehmer has a very careful, detailed description, and also some excellent drawings, and being a careful, conservative investigator, his work is particularly valuable.

Later workers are Takamine, Juhler, Jörgensen, Hansen, Klöcker, Schiönning, and Sorel. Takamine is a Japanese chemist who introduced the mould into this country for the purpose of its introduction into distilleries and breweries, his idea being to do away with the malting of the grain. This is to be effected by mixing the mould with the crushed grain in order to bring about the diastasic change in the starch by a less clumsy and more economical manner than the malting. He took out a patent in this country on the mould, his patent treating of its diastasic function and its transformation to a yeast. The method was introduced into a distillery and there Juhler obtained the mould, and took it to Denmark for study in Jörgensen's laboratory. Juhler claimed that the mould could be changed under certain conditions to a yeast, and Jörgensen indorsed him, and carried the assertion still farther by claiming that other moulds as well as A. oryzae possessed this property. Sorel got like results to those of Juhler and Jörgensen, but he makes a still further assertion in that he claims to reproduce the mould from the yeast when he sowed the yeast in a "not-quite-pure" condition upon the rice. The "not-quite-pure" condition undoubtedly accounts for his results.

Hansen took the opposite view in disclaiming alcoholic fermentation, and conversion of the mould to a yeast. Klöcker and Schionning, who worked in Hansen's laboratory, agree with Hansen's view of the matter, and this conclusion was arrived at after an extended investigation of the mould, this investigation including a repetition of Juhler, Jörgensen, and Sorel's experiments with original material furnished by Takamine, and also pure material. Wehmer in a second paper also agrees with the non-production of yeast and alcoholic fermentation, and states that there are two organisms that take part in the saké brewing, and that Takamine, Juhler, and Jörgensen did not discover the genetic relationship of the two, This, however, does not state the true condition of the case, for Jörgensen was aware of the two organisms present, and states that there is no genetic relation between the two.*

Other workers upon the mould are Atkinson of Tokio, who treated it from the industrial point of view, as did also Hoffman and Korschelt. Cohn, Büsgen, and Ikuta followed, their work being mainly along the same lines, though each one gave some additional information. The morphological and physiological characteristics were carefully worked out by Kellner and his assistants, Mori and Nagaoka.

There has been a large number of investigations made upon the life history of the fungus and yet there are some points left that are not clearly given, as the peculiarities of form due to varying conditions, and also the failure to take advantage from the industrial point of the power which the mould is said to possess of causing alcoholic fermentation. In an English medical journal the statement is made that the mould is capable of producing a strong and certain alcoholic fermentation, and is much more resistive to foreign organisms than is yeast; that for these reasons it would be much more effective and economical than yeast in the fermentation of bread.

MORPHOLOGICAL.

The material for the following experiments was some of the so-called "original" material, obtained from Takamine. This original material is a portion of koji, which was grown without any special precautions to keep it pure. Pure cultures were made from this material, and were also used.

*Jörgensen, A.; "Micro-organisms and Fermentation," p. 93, 1893.

A. oryzae is a mould of a yellowish green color when seen in the mature stage. The color varies with the age of the plant and also with the medium upon which the plant is grown. Favorable solid media are bran, rice, and wort gelatine. On rice and wort gelatine the young growths are of a light yellow green, the color being due to the numberless conidia formed. As the growth ages, the color changes to dark olive green. On plate cultures the mycelia are usually in colonies, due to the massing and germination of a number of conidia in one spot; as a result, the plate presents a very irregular growth appearance (photograph 1). On bran the color of the young growth is much darker than that of the same age on rice, and in old growths the color is brownish olive to dark brown. In very old growths not a trace of green appears.

The mycelium is a mass of fine, fleecy filaments, very much branched, and containing numerous septa. Wehmer states that the branching and septa were not easily seen, except with high magnification, but I had no difficulty in seeing both features with low powers, as photographs 2, 3 will show. These were taken from gelatine-plate cultures. The magnification is 75 diameters. In young growths the filaments are filled with a finely granular protoplasm, which becomes much vacuolated as growth proceeds (photographs 4, 5). The filaments vary much in diameter even in the same culture, the main filament being large, while the branches taper, sometimes these being extremely fine. In old cultures the filaments become very large, thick and rough-walled (photograph 6). They are always colorless.

The conidiophores can usually be distinguished from the mycelial hyphae as they gradually enlarge to the spherical end. The length varies to such an extent that any figures would not mean anything. The conidiophores are sometimes short branches at right angles to the filaments from which they arise sometimes so long that their connection is somewhat difficult to determine. Büsgen gives the length of the conidiophore as .5 mm., Schröter, 1 mm., while Wehmer merely states that they vary in length. They become much enlarged in old cultures, the walls become very much thickened and roughened (photographs 8, 9).

In young growths the sterigmata are short and regular, and vary from a few in number to sufficient to completely cover the spherical head; but in older growths, especially when submerged, they become septate, sometimes a sterigma developing into a conidiophore, which on its end

again develops sterigmata. These peculiarities are found readily in moist chamber developments (photographs 10, 11).

The conidia are spherical and are formed by an abstriction from the ends of the sterigmata. They are colorless and smooth-walled when first formed and when grown submerged, but very soon develop a yellow color, which darkens to a green, and when old, olive and brown. As soon as the conidia developed in the drop in a moist chamber reach the air, the walls thicken irregularly and assume a fine warty appearance. Photograph 7 shows the submerged head, photograph 12, older conidia grown in the air. No pictures could be taken that give an adequate idea of the number of conidia formed in a chain, as in their growth they extend so far beyond the plane of the water drop that it was impossible to focus them. And again they are so lightly held together that any attempt to mount them under a cover-glass causes them to separate.

The formation of conidia is the only method of reproduction known; no perithecia have been observed, though they have been mentioned by the earlier investigators, but this has come about through the erroneous designation of the fungus as a Eurotium.

PHYSIOLOGY.

To determine if the mould were capable of causing alcoholic fermentation, the mould spores were shown in ten per cent. solutions of maltose, dextrose, lactose, and sucrose, also wort, all in fermentation tubes. No gas was generated nor was any alcohol formed. The mould, however, grew much better in dextrose and maltose than in lactose and sucrose. The lactose growth remained meager, but the sucrose was merely slower, finally reaching the same extent of growth as the dextrose and maltose.

To test the action in bread, cultures in wort were made of the mould and also of a yeast which gives a vigorous fermentation. After these had grown for five days, sponges were made in which the yeast and mould were used and equal quantities of the other ingredients. In one set the yeast was used alone, in another the mould alone, while in a third the yeast and mould were used together. The sponges were allowed to ferment, then kneaded into dough, and again fermented, at the end of which time they were baked. The yeast sponge fermented most vigorously, the yeast and mould much slower, while the mould sponge showed but very little change. The yeast and mould together took an hour longer than the

yeast alone to reach the same degree of fermentation. The loaves from the yeast were of sweet taste and odor, and even-grained. Those from the mould were soggy and heavy, had a sweet odor, but left a sharp aftertaste. The loaves from the yeast and mould were very like those from the yeast, but also left the sharp aftertaste, though this was not unpleasant. Four persons having no knowledge of the constituents of the loaves, selected the ones made from yeast alone as being the best bread.

In testing the germinative power, cultures were made in wort, wort gelatine, Pasteur solution with the four sugars, lactose, dextrose, maltose, and sucrose from inoculating material that varied in age from very young through different periods to one year and eleven months, and which had been grown upon rice, bran, wort gelatine, wort, and Pasteur solution containing the different sugars. The results show that the germinative power lessened with age, but a more important factor than age was that of the original medium in which the culture had been made. Some of the growths from the wort gelatine plates had entirely lost their germinative power, while others were weakened. Wehmer states that the age of the inoculating material made no difference in germinative power, neither did the medium upon which it had been grown.

For ascospore formation young conidia were sown upon gypsum blocks in the usual way for obtaining yeast spores, and in about a month's time rounded masses of protoplasm, resembling yeast spores, were formed in some of the cells, though no cell-wall could be determined for these spore-like bodies. The same spore-like bodies were formed from the protoplasm in mycelial filaments undergoing the same treatment.

No experiments were made directly to determine the diastatic action, as work upon this has been done quite extensively by chemists.

In conclusion I would state that so far as any experiment would show, there was no indication that A. oryzæ has the power of causing alcoholic fermentation, nor of being transformed through any conditions whatever into a yeast. Neither can it be used effectively in bread-making.

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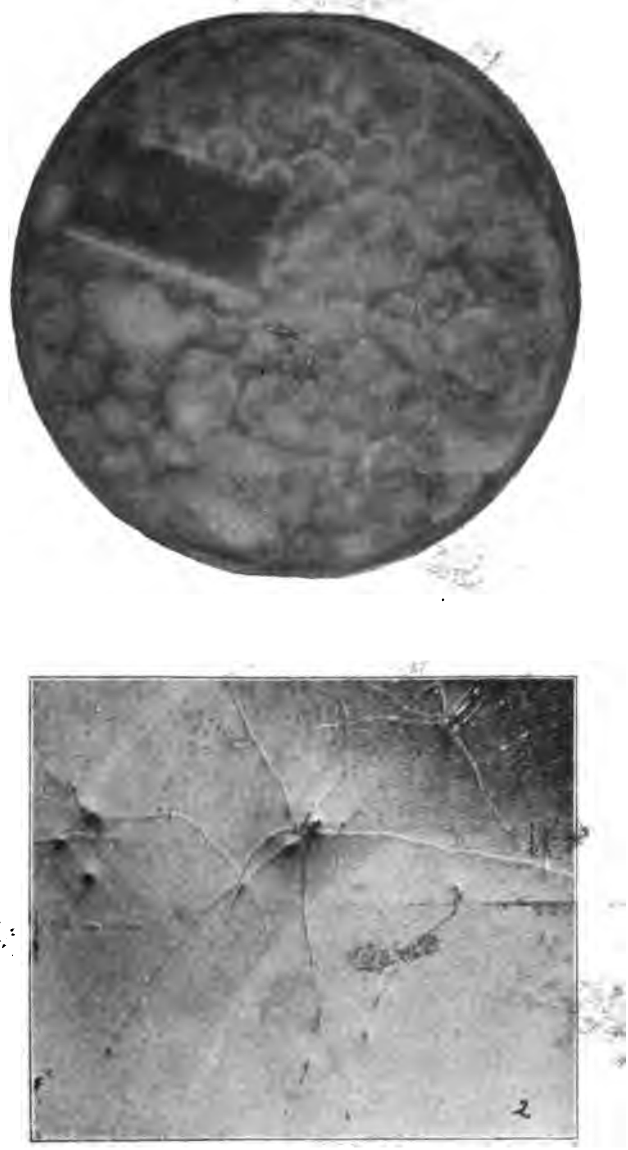
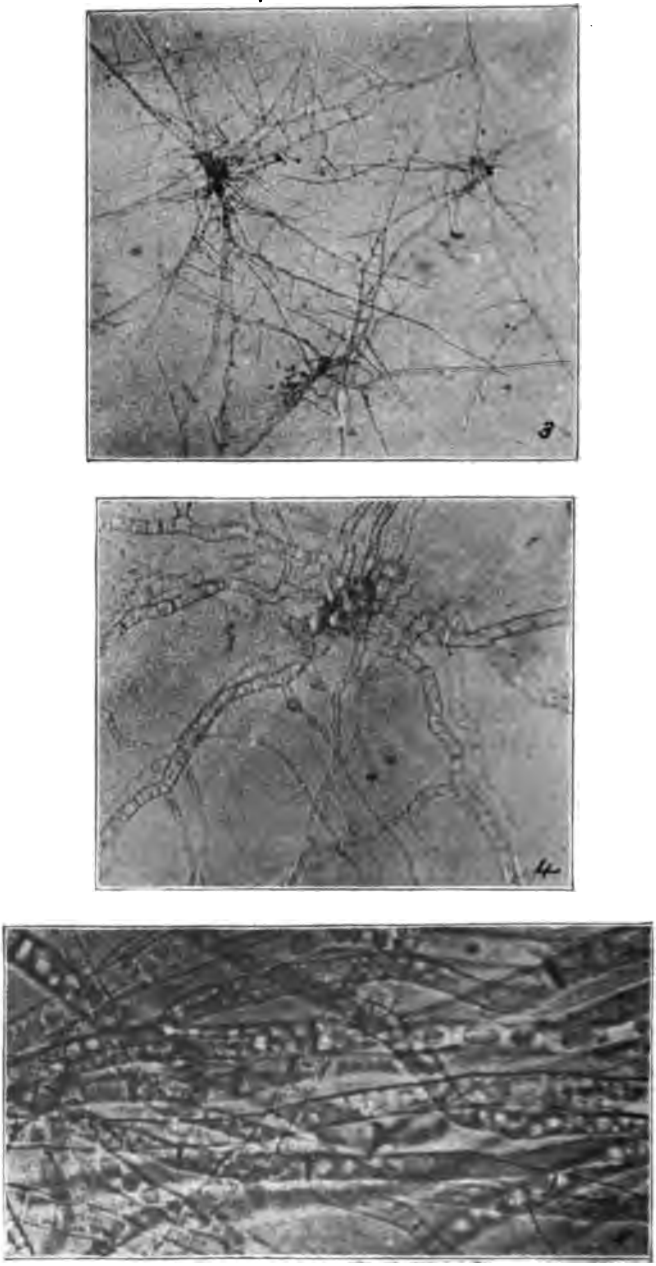
EXPLANATION OF PLATES.

1. Wort gelatine plate culture, about a week old. × ⅔.
2. Germination of conidia in moist chamber. × 75.
3. Germination of conidia in moist chamber, in more advanced stage.
4. Same as 3, but higher magnification. × 495.
5. Filaments from wort gelatine plate culture. × 95.
6. Filaments from wort gelatine plate culture, ten months old. × 495.
7. Conidiophore grown in moist chamber, four days old. × 495.
8. Conidiophore from same source as 6. × 495.
9. Conidiophore from same source as 6. × 495.
10. Moist chamber growth, three weeks old. × 495.
11. Moist chamber growth, three weeks old, showing sterigma developing as conidiophore. × 495.
12. Spores from plate culture, three weeks old. × 495.



Golden on Aspergillus oryzæ.



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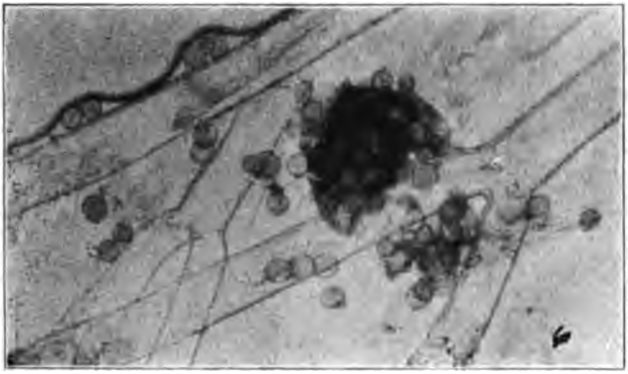

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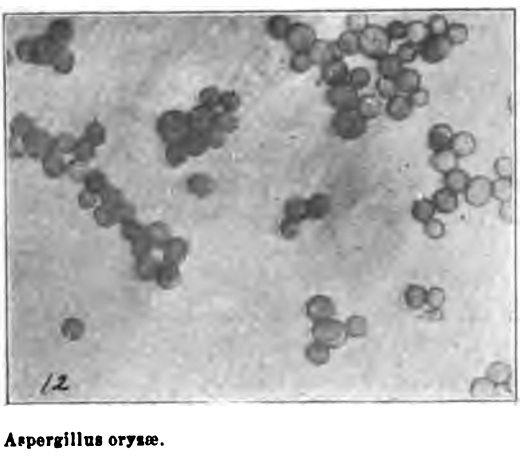

Golden on Aspergillus oryzæ.

A RED MOULD. BY RALPH GILSON CURTISS.

The mould with which this paper has to deal was first found at Purdue University upon a plate culture which had been exposed to the air. It was at first supposed to be a mixture of a mould with a yeast, and this idea was a natural one in view of the behavior of the form when grown upon gelatine cultures. The characteristics exhibited during growth in this way seem to partake both of those ascribed to moulds and those which we are accustomed to associate with yeast forms. A mycelium is developed first, the early stages of which resemble in their growth those of the common moulds, but which soon disappear completely, its place being taken by a reddish film which covers the entire surface of the culture and which is thickly dotted with red specks. This dotted appearance is what gave rise to the supposition that a yeast was present in company with the mould, and it was only after a series of attenuated cultures had been made from the original plate that the true nature of the growth was ascertained.

It is evident that in a form whose growth shows such a remarkable and abrupt transition from the true mould stage to a yeast-like stage, we have a subject for research which should amply repay the most careful investigation. As soon as it was determined that both appearances were due to the growth of a single mould, cultures were made for the purpose of following its life history.

In fluid cultures the best results have been obtained with wort and Pasteur's solution. On wort kept at room temperature, a growth is apparent in twenty-four hours, and in forty-eight hours colonies are visible throughout the medium as well as covering the surface.

The peculiar red color is noticeable even in the thinnest portion of the growth, that on the surface showing as a pinkish film. This film, when broken by the platinum needle for purposes of examination, is found to possess a considerable toughness and is difficult to remove from the tube, except in large pieces.

A point which will receive more attention in later investigations is that when grown upon sugar solutions, all that portion of the growth which is exposed to the air turns black as it ages, while cultures made at the same time upon wort retain the characteristic red color.

The filaments of this mould vary considerably in size, according to age, the younger ones having the lesser diameter. They are divided at

frequent intervals by septa, especially in the older portions; the septa, however, seem in no way connected with the position of the branching hyphæ. The young filaments, which are usually filled with protoplasm that is transparent, sometimes contain a thread of protoplasm which is highly refractive and which shows no vacuoles. It is possible that it is this thread of refractive protoplasm which, in rounding off and becoming denser, produces the small spore-like bodies which are found in the mycelial cells.

The question of the reproductive methods of the red mould has been the chief source of difficulty in its study, and so far as the work has been carried these methods have not been fully determined.

As regards the formation of conidiophores this mould is markedly different from the commoner ones. In spite of the most favorable vegetative conditions having been given, both as to the kind of nutritive solution used in the moist chamber, and as to the temperature, no conidiophores have been discovered. A kind of division into cells, which is perhaps analogous to the formation of conidia in other moulds, takes place (Fig. 1), but observations as to the true significance of the division are not complete. The nearest approach to the formation of conidiophores is in the hypha shown in Fig. 2. Here a rounding takes place in the terminal cell and the hypha back of this rounding is divided by an extraordinary number of septa.

However inadequate the determination of vegetative reproduction, proofs of sexual reproduction have been more abundant. The red specks to which I have referred as being so thickly distributed over the surface of the gelatine cultures occur also in the tube cultures and in the moist chamber. When a culture is examined under the microscope, these specks are seen to be dense, irregularly shaped bodies of extremely varying sizes. (Fig. 3). Some are many times the size of others which have apparently reached the same stage of maturity. They are formed by the interlacing of the filaments and are found completely developed in so short a time that it has been impossible to secure the intermediate stages for photographing. As the interlacing of the filaments goes on, the massing becomes denser at some points than at others, and here these rough, compact, tuberous bodies are found. (Figs. 3, 4, and 5.) Unfortunately their thickness prevents their successful photographing (since it is impossible to focus with the microscope on more than one plane at a time). These bodies conform to a certain extent to the description of sclerotia but their function is evidently not that of a resting body formed under adverse conditions. On

the contrary they are formed almost immediately under the most favorable conditions and occur in all cultures. They rather resemble sporocarps in their function, but they do not contain asci, so far as has been determined.

When broken open soon after formation, these bodies are found to contain a large number of small yeast-like cells, which have a cell wall and are filled with protoplasm which is at first clear but soon shows a number (usually two) of denser, spore-like granules. The covering of the body is a rough yellowish wall.

If the yeast-like cells which these bodies contain were seen unaccompanied by any mycelial growth, it would be extremely difficult to distinguish them from the cells of a true yeast. This would appear to give considerable support to the theory that yeast and mould can be developed from the same growth interchangeably, but in reality it does not. Every attempt has been made to secure budding and fermentation from these cells but so far neither has been found. The growth of the cell is in every case by the sending out of a true mycelial filament.

What appears to be another method of producing a body similar to the one I have mentioned is shown in photographs 6 and 7. It may be that one of the filaments seen there fertilizes the other, though at any rate the resulting body is similar in color and appearance to the one formed by the interlacing of the filaments.

Three stages in a peculiar formation are shown in photographs 8, 9 and 10. The process consists in the coiling together in a peculiar manner of two hyphæ which may or may not arise from the same branch of the mycelium. Figures 8 and 9 show the coiling as it begins and figure 10 shows it in a more advanced stage. The body in figure 10 appears to have a definite structure, being formed by the coiling of two hyphæ—whose origin is visible—from the same mycelial branch.

In conclusion it may be stated that the investigations are by no means considered complete, but that it is to be hoped that additions can be made to our knowledge in the near future.

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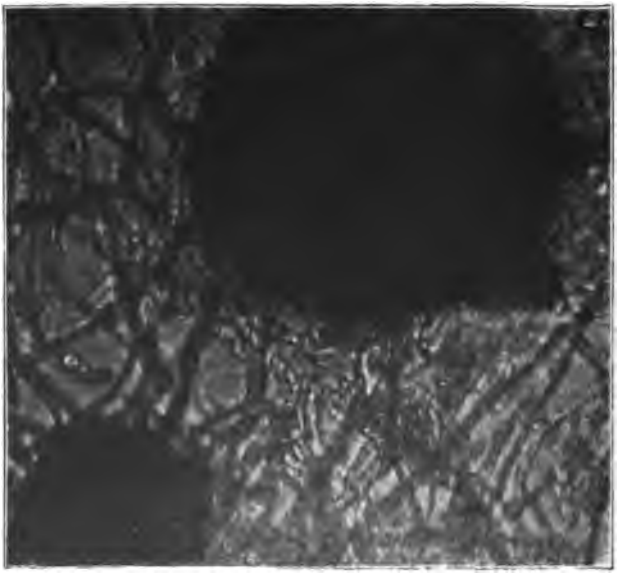
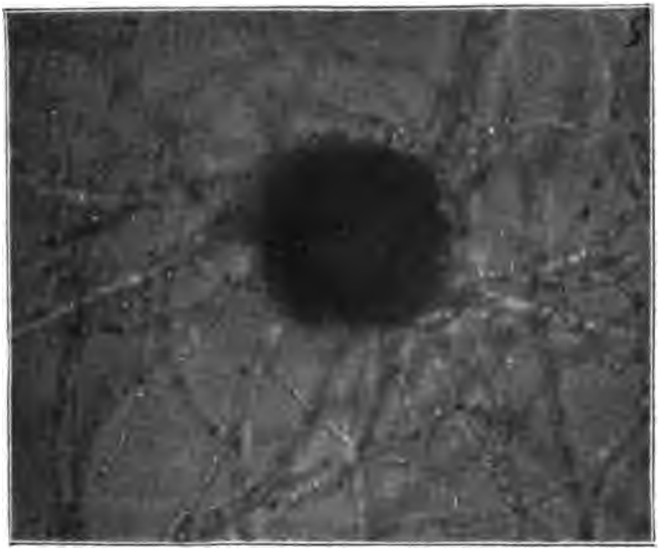
EXPLANATION OF PLATES.

No. 1. Culture on lactose five months old. ×495.
No. 2. Culture in moist chamber on wort three days. ×495.
No. 3. Culture on wort gelatine two days old. ×75.
No. 4. Culture in moist chamber on wort six days. ×495.
No. 5. Culture in moist chamber on wort six days. ×495.
No. 6. Culture in moist chamber on wort seven days. ×495.
No. 7. Culture in moist chamber on wort eight days. ×495.
No. 8. Culture in moist chamber on wort eight days. ×495.
No. 9. Culture in moist chamber on wort eight days. ×495.
No. 10. Culture in moist chamber on wort eight days. ×495.

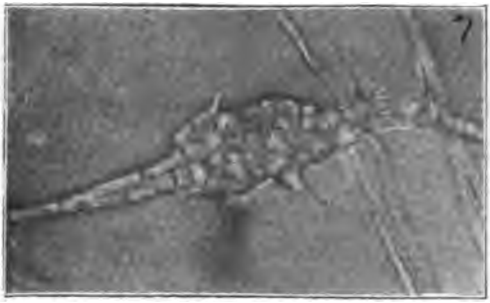
Curtiss on Red Mould.

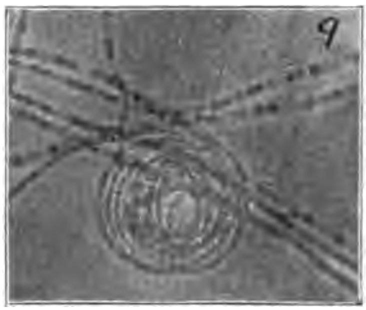


Curtiss on Red Mould.



Curtiss on Red Mould.





Curtiss on Red Mould.

AFFINITIES OF THE MYCETOZOA. BY EDGAR W. OLIVE.

The chief interest which invests this group of low organisms lies in the fact that the individuals possess a dual relationship; during one stage of their existence resembling certain members of the animal kingdom, while during another, they bear many resemblances to the plant kingdom, through the fungi, with which they agree somewhat in the structure of their organs of reproduction and spores.

The spores, on germinating, produce swarm-cells and plasmodia, instead of mycelium. The swarm-cells, or myxamœbæ, resemble the naked amœbæ of the animal kingdom, while the remarkable plasmodium, although there is no parallel among undoubted animals, seems to partake almost wholly of characters agreed by scientists to be clearly animal.

The sporangium has a membranous wall sometimes resembling the cellulose walls of plants, and its cavity is filled with free spores and in many species a scaffolding support of threads called the capillitium. Probably the resemblance of this reproductive stage to the fungi is of very small amount, being confined to purely external resemblances.

The *Mycetozoa*, as defined by DeBary, embraces two distinct groups, the *Myxomycetes* of Wallroth, and in addition the *Acrasieæ* of Van Tieghem, evidently resembling each other very closely in the fact that their spores send forth swarm-cells which exhibit amœboid movements. The only important difference between the two is the formation of plasmodia by the coalescence of swarm-cells in the former and the formation of pseudoplasmodia by the aggregation of the swarm-cells in the *Acrasieæ*. It was regarded by DeBary as easy to conceive of the common origin of these two closely related groups or of the development of the one from the other. He says that probably the *Myxomycete* plasmodium was evolved from the aggregation plasmodium, since the latter appears to be the less complex form and its fructification much simpler; possibly the development took place in the converse order.

Botanists seem never to have questioned the homology of the pseudoplasmodium of the *Acrasieæ* with the plasmodium of the *Myxomycetes*. This plasmodium is strictly vegetative; during this period nourishment is imbibed. The pseudoplasmodium is not vegetative; it is simply preliminary to the reproductive stage by the aggregating of individuals. It follows, then, the strictly vegetative stage. If lack of analogy can thus be

reasoned into lack of homology, the pseudoplasmodium and plasmodium may not correspond in type of structure.

To DeBary's oft-quoted, but rather ambiguous statement of his estimate with regard to the position of the *Mycetozoa* is due much of the unsettled condition of the group. He says: "I have since the year 1858 placed the *Myxomycetes* under the name *Mycetozoa* outside the limits of the vegetable kingdom, and I still consider this to be their true position." Strangely, however, he included the *Mycetozoa* in all his subsequent botanical works, as if he lacked the courage of his convictions; and other writers of text-books have continued to do the same.

DeBary based his views on his belief that the *Mycetozoa* in their evolutionary development are the terminal members of a series of forms. In his opinion they, like the puff-balls, do not connect with any higher group. He contented himself, then, with seeking for their possible affinities with the inferior forms from which they must have proceeded. Even in this search, he found it impossible to establish exact homologies, for he limited himself to strict resemblances in form, structure, and mode of life. All agree with his conclusions concerning the original starting point; that we are led by a very short step to the naked *Amœbæ* of the animal kingdom. The *Amœbæ* are organisms having the amœboid movements of the swarm-cells of the *Mycetozoa*, which multiply similarly by successive division, but which do not form plasmodia or aggregations in any way. Indeed, in *Sappinia*, which Dangeard places among the *Acrasieæ*, the *Amœbæ* do aggregate at the ends of straws. *Guttulina*, one of the *Acrasieæ*, is really a naked Amœba, differing only in the aggregation of its microcysts into heaps, or sori.

Bütschli has pointed out the probability of the starting point of the naked amœbæ being groups of very simple organisms known as the *Flagellatæ*; and since the swarm-cells of the *Mycetozoa* are furnished with cilia and have all the characters of the simpler *Flagellatæ*, DeBary goes back to these forms as the converging point of the plant and animal kingdoms.

Lister has established beyond a doubt the fact that certain of the *Mycetozoa* have the power of digesting solid food. In his experiments on the plasmodium of *Badhamia*, he proved that it had a remarkable power of discriminating between different foods. He suggests also that another species, *Chondrioderma difforme*, probably uses bacteria as its principal

food. He has repeatedly seen them caught by the pseudopodia of the swarm-cells, ingested in the vacuoles, and gradually dissolved.

Yet, notwithstanding the fact that there are some exceptions to the rule, DeBary definitely states that "the food is taken in during the swarm-cell condition only in the fluid state or state of solution, and this is also the case, at least in most instances, with the plasmodia."

It is quite evident, as Massee has shown, that DeBary deduced all his reasons against the vegetable nature of these organisms from the vegetative stage. In his monograph on the group, Massee combats step by step the position taken by DeBary. He gives the following arguments in support of his views: (1) The frequent presence of cellulose in the cell walls of spores and sporangia; (2) the frequent separation from the protoplasm, during the period of spore formation, of a substance homologous with the substance separated during the same period in the *Ascomycetes*, etc. This forms the capillitium. (3) The frequent separation of lime from the protoplasm at the commencement of the reproductive stage. (4) Agreement with many fungi in contrivance for spore dissemination. (5) The production by free cell formation of spores protected in the early stage by a wall of cellulose, which eventually becomes differentiated, and, as stated by DeBary, "behaves toward reagents in a similar manner to cuticularized plant cell-membranes and to spore-membranes in the fungi." (6) The analogy with undoubted members of the vegetable kingdom, as *Hydrodictyon*, where the naked motile swarm-cells coalesce to form a net.

Massee claims that the observations upon the vegetative stage alone furnish no more convincing proof that the phenomena peculiar to it are incompatible with a condition of vegetable organisms than are the amoeboid forms in such algæ as the *Volvocineæ*.

The presence of cellulose in the stalk cells and spore walls of the *Dictyosteliaceæ* may be adduced as an argument for the plant affinities of the higher *Acrasieæ*.

Thaxter suggests another possible line of genetic connection of the *Mycetozoa* with plants, through the *Myxobacteriaceæ*. He places the *Myxobacteriaceæ* in the *Bacteria*, or *Schizomycetes*, on account of the homologies in the reproduction which they present. In one stage they are a mass of rods, having a slow progressive motion and reproducing rapidly by fission. They are distinguished, however, from other bacteria by having two definitely recurring periods in their life cycle—"one of vegetation, the other of fructification or pseudofructification through the simultaneous and

concerted action of numerous individuals." During the nutritive stage, the rods lie separate. Through some contagious impulse they concentrate toward central points, piling up on one another, and gradually change into spores.

As is cautiously suggested, "the resemblance (to the *Acrasieæ*) might be purely accidental," yet the general character of the corresponding periods is practically identical, except for cell differences of the organisms concerned.

If we assume that the pseudoplasmodium of the *Myxobacteriaceæ* indicates a genetic connection with that of the *Acrasieæ*, then the *Mycetozoa* have affinities with higher plants through the *Bacteria*, which are evidently derived forms of the fission-algæ. At any rate, as suggested by Thaxter, "caution is necessary in accepting the views of those who would unceremoniously relegate the *Mycetozoa* to the domain of pure zoölogy."

Morphological Characters of the Scales of Cuscuta.

By Alida M. Cunningham.

The work undertaken and the line of thought pursued throughout has been that of making a revision of the family *Cuscutaceæ* of North America. This work was commenced at the beginning of the present university year and has been pursued since that time with the assistance of Dr. Stanley Coulter of Purdue University. The only complete work on this family which has been given to the public is that of Dr. Engelmann, published in 1859. Since that time a few new species have been added to those named in his work, and some of these have been classified by Dr. Engelmann himself. Like all works of any magnitude, the original is imperfect and incomplete.

This family is one presenting much difficulty, because there are so few characters which can be used in determination and many of the flowers are so minute as to necessitate the constant use of the microscope in examination. For this reason much classification has been done in the past by mere comparison of the unnamed specimens with the named ones. After a study of these plants we are convinced that such a classification is misleading and extremely inaccurate. Again, the plants have such a range of variation, yet merge into each other so closely in some of their

parts that it is only by the utmost care and closest scrutiny that they may be determined, and a dissection of the flower is invariably necessary. Many of the species have also a great similarity in habit of growth and the arrangement of the inflorescence, which is confusing and liable to mislead one who attempts a mere comparison.

The sketch here presented does not cover the subject originally undertaken, but is merely one of the many interesting features in this family of plants. This study of the scales of *Cuscuta* was suggested in the course of the study by reason of the fact that the observations made thus far do not, in many respects, coincide with the statements made by Dr. Engelmann in his work. He describes the scales as being epistamineal and that they are evidently lateral dilatations of the lower part of the filaments, or a sort of stamineal crown attached at the base of the corolla, but not a duplication of the corolla.

In the study of this subject we have made constant use of the microscope, making sections of flowers in various directions, and are forced to conclusions quite different from those of Dr. Engelmann. In the course of the work it was noticed that in some species the filament of the stamen extends under the apex of the scale, in others the base of the filament is above the apex of the scale, and in still others the filament can be traced nearly to the base of the corolla, while the scale forms two lateral wings, one on each side of the filament. For this work specimens from each of the three groups were examined. Longitudinal sections were made through the corolla, with its attached stamen and scale, and a careful study showed that the scales have their origin from the corolla. The stamens also originate from the corolla, but at a different level from the scale, so that they cannot possibly be attached to each other. However, in the third section a few species showed some connection between the scale and the filament; but while there may have been a slight attachment of these parts in individual specimens, yet the examination of other sections fully demonstrated the fact that the origin of the scale is unquestionably from the corolla, and the base of the stamen is slightly above that of the scale.

The results of these examinations, so far as made, confirm us in the belief that the scales are not epistamineal, and do not form a stamineal crown, but are petaloid in their origin and are in the nature of a duplication of the petals.

Geographical Distribution of the Species of Cuscuta in North America.

By Alida M. Cunningham.

In the Year Book of the Agricultural Department, published in 1894, C. Hart Merriam, Chief of the Division of Ornithology and Mammalogy, gives a revision of the work theretofore done in an endeavor to divide the country into distinct zones according to the plant and animal life found therein. And, since the distribution of all life depends so completely upon rainfall and temperature, these have been made the principal guides in locating the lines separating these zones, taking into consideration both latitude and elevation. He has divided North America into five zones as follows: Boreal, Transition, Upper Austral, Lower Austral, and Tropical.

In the course of the study for the purpose of making a revision of the genus Cuscuta it was found of interest to note the geographical distribution of the genus in accordance with the plan adopted by Mr. Merriam. So far as the work has progressed, the material examined has been that contained in the herbaria of Harvard University, the botanical gardens of St. Louis, Missouri, and Purdue University, in all about 450 specimens. Among them, according to the nomenclature heretofore adopted and still in use, we find thirty-two species and seventeen varieties, which are distributed throughout the five zones in the manner given below. But there is found here the same difficulty that has confronted us on different occasions before, *i. e.*, that the forms are so badly confused at present that any arrangement which might be made now is almost sure to need revision after a critical study of the genus. According to the present nomenclature, the distribution is as follows:

Potosina, *Palmeri*, *Americana*, *corymbosa*, *tinctoria*, *Jalapensis*, *mitræformis*, *floribunda* and *gracillima* are confined to the tropical zone and constitute the greatest number found in any one zone.

The next greatest number found in only one zone is in the Transition. They are *Epithymum*, *denticulata*, *rostrata* and *epilinum*.

Californica and *subinclusa* are found in the Tropical and Transition.

Leptantha and *chlorocarpa* in the Upper Austral and Transition.

Applanata and *inflexa* in the Upper Austral.

Cuspidata, *compacta*, *decora*, *Gronovii* and *arvensis* are distributed over the Upper Austral, Lower Austral and Transition.

Squamata and *odontolepsis* in the Tropical and Upper Austral.

Tenuiflora is found in three zones, i. e., the Transition, Upper Austral and Boreal.

Glomerata in the Upper and Lower Austral.

Umbellata in the Tropical, Upper and Lower Austral.

Obtusiflora in the Tropical, Transition and Upper Austral.

Salina in the Transition and Boreal.

Exaltata is found only in the Lower Austral.

The above facts may be presented in tabular view as follows:

Boreal.	Transition.	Upper Austral.	Lower Austral.	Tropical.
Salina.	Salina.			
Tenuiflora.	Tenuiflora.	Tenuiflora.		
		Glomerata.	Glomerata.	
	Californica.			Californica.
	Subinclusa.			Subinclusa.
		Umbellata.	Umbellata.	Umbellata.
	Obtusiflora.	Obtusiflora.		Obtusiflora.
	Epithymum.			
	Epilinum.			
	Denticulata.			
	Rostrata.			
		Squamata.		Squamata.
		Odontolepis.		Odontolepis.
			Exaltata.	
		Inflexa.		
		Applanata.		
	Cuspidata.	Cuspidata.	Cuspidata.	
	Compacta.	Compacta.	Compacta.	
	Decora	Decora.	Decora.	
	Gronovii.	Gronovii.	Gronovii.	
	Arvensis.	Arvensis.	Arvensis.	
				Potosina.
				Palmeri.
				Americana.
				Corymbosa.
				Tinctoria.
				Jalapensis.
				Mitræformis.
				Floribunda.
				Gracillima.
	Chlorocarpa.	Chlorocarpa.		
	Leptantha.	Leptantha.		

Notes on the Germination and Seedlings of Certain Native Plants.

By Stanley Coulter.

In the study of the phanerogamic flora of the State, some problems respecting the distribution or rather the non-distribution of certain species seemed to require for their solution somewhat extended germination experiments. These experiments have been in progress for three years, under conditions to be indicated later.

Incidentally the seedlings were carefully studied, more especially as to their resistance to temperature and moisture changes, in a less degree as to the form and arrangement of their earlier foliage leaves, since these, perhaps, in many cases may be regarded as representing inherited forms, while the later leaves stand for adaptive responses to light intensity and other ecologic factors. The results of the observations upon this point have not been sufficiently considered to warrant their presentation at this time, except in a few instances which indicate that many suggestions as to relationships would probably be one of the results of such a study.

It will be recalled, when we consider our native plants, that the increase in numbers and the consequent amount of territory occupied by any specific form bears no direct relation to the number of seeds it may produce. Indeed, the production by a given plant of a vast number of seeds, with adaptations for a wide dispersal, should, perhaps, be taken as an index of the intensity of its struggle for existence, and stand as a sure sign that, save through some change in ecological factors, the form will do little more than maintain itself in nature.

This view, which it will be remembered was advanced by Weismann, is being confirmed by observations upon plants. The setting of a large number of seeds stands not as the sign of a rapid increase in numbers of the form, but rather the reverse. An example or two may emphasize the statement.

The common nightshade *(Solanum nigrum)* is a plant with which all are familiar. Where it obtains a foothold it usually holds its own, but rarely becomes dominant or so increases in number from year to year as to attract attention. From one of these plants which bore forty-three berries and was still flowering, I took three berries and planted them after having broken the outer walls. *One hundred forty-two* seedlings appeared. Surprised at the result I planted three other seedlings similarly treated, being especially careful to eliminate error. In this case *one hundred eighty-seven* seedlings appeared. This would indicate that each berry contained on an average at least fifty viable seeds, and as there were over forty berries, the potential product from that single plant was over two thousand plants.

From the ordinary *Scrophularia*, germination percentages ran from fifty-six to seventy in the favorable conditions of the laboratory, indicating an almost incredible possible increase from a single plant. Yet every

botanist knows that this plant makes no visible increase in numbers from year to year. The great number of capsules filled with seeds is but the sign of its intense struggle.

In many cases the causes which hold in check the undue increase of a specific form are evident. The law requiring that stock should be kept within bounds, modified in very marked degree the flora of the State, and in certain regions has served to cover stripped hills with a new timber growth. But there are cases in which the number of seeds produced is so enormous, the means of dispersal so various and ingenious, and the dispersal itself so sure, that we wonder that the increase is no more rapid. In this category we find notably the composites. Considering their myriads of seeds and their perfect means of seed dispersal, their increase in numbers is insignificant. Indeed, in many cases special protective devices have been developed in order that they may maintain their place in nature.

It is evident that factors other than those ordinarily limiting plant distribution are operative in limiting the distribution of the composites, or that the composites are peculiarly sensitive to conditions which do not materially affect the majority of plants. The theory of special limiting factors seemed scarcely worthy of consideration. It was therefore presumed that some, at least, of the ordinary factors were more effective than in other cases, and that in all probability there was a peculiar sensitiveness to these changes at some particular stage of development. The experiments were undertaken with the hope of throwing some light upon these points. The conditions of the experiments have been varied from time to time as experience suggested, and to such an extent as to preclude tabulation in the limits of this paper. Conditions may be summarized as follows: Two kinds of soil were used—a loam mixed with sand and a leaf-mold. In both cases the soil was carefully sifted and packed in the pots in order to prevent subsequent settling. As regards moisture, three conditions were used—saturated, moderately moist and extremely dry. The percentage of water in the soil was not carefully worked out, but was roughly estimated to range from 25 per cent. in one extreme to between 80 and 90 per cent. in the other. Planting was either surface or at about the depth of the seed. The average temperature in the first series of experiments was 26.5° C., with extremes of 20° C. and 31° C. In the second and third series the average temperature was 24° C. As far as could be determined by inspection only perfect seeds were used. As a matter of course, control experiments served as checks upon results,

From the results of the experiments the following conclusions seem deducible.

FIRST.—*The germination percentage in the compositæ is low as compared with that of the other families examined.*

This statement has its apparent exceptions in *Arctium Lappa* and *Cnicus lanceolatus*, which show high percentages. That these are exceptional, however, will be shown later. From the experimental cards the following table is drawn:[1]

	Per cent.
Arctium Lappa	93.3
Cnicus lanceolatus	89.3
Bidens bipinnata	37.5
Bidens frondosa	30.0
Lactuca Canadensis	37.5
Lactuca Scariola	25.0
Solidago Canadensis	12.5
Anthemis cotula	12.5
Cnicus muticus	10.0
Aster Shortii (one year)	
Ambrosia (one year)	
Vernonia fasiculata (one year)	

Germination percentages shown by forms in other families are as follows:

Solanum nigrum, 187 seedlings from three berries.

	Per cent.
Datura Tatula	100.0
Abutilon Avicennae	89.0
Scrophularia nodosa	70.0
Plantago Rugellii	62.5
Rumex Acetosella	56.7
Malva rotundifolia	45.0
Capsella Bursa-pastoris	45.0
Nepeta Cataria	
Chenopodium album	

[1] These are taken from over 200 experimental cards and are fairly typical of the series. Experim nts with ordinary germinating apparatus confirmed these results.

These percentages are not exceptional, having been repeatedly obtained. I have not been able to secure germination in Chenopodium, a fact possibly due to the late collection of the material.

SECOND.—*In most cases the achenes show the highest germinating percentage if collected at about the middle of the flowering season.*

If, for example, the flowering period is from July to October, achenes collected in the latter part of August or first of September will give a higher germinating per cent. than those collected at any other season. This is true in all forms studied, with the exception of *Arctium*. The non-viability of the later achenes may be explained as due to the action of frost. That of the earlier achenes is not so readily explained. In *Arctium* the achenes show a ready viability at all seasons. In the case of Bidens it is possible that the later achenes might show a fair percentage of viability, as no late collections of this genus were made. The difference in viability at different floral periods does not seem to exist in the other families studied. On the contrary, in the case of Abutilon and Solanum, the highest percentages were obtained from the seeds collected very early in the season.

THIRD.—*For the most part the central achenes of the head are not viable, and the same condition is frequently found in the outer rows.*

In all cases the largest germination percentage was obtained from achenes taken about midway between the center and periphery of the head. An exception to this statement is perhaps found in Helianthus, in which, in a single experiment, the central achenes were found to show a high germination percentage. A consideration of the order of maturing of the flowers in the composite head taken in connection with the mode of pollination furnishes the probable explanation of this fact.

FOURTH.—*The seedlings of all composite forms studied, were found to be particularly sensitive to both temperature and moisture changes.*

Very slight changes in either of these conditions, especially if sudden, proved fatal almost without exception. An increase in temperature of 5° C., brought about in thirty minutes and continued for three hours, killed all the seedlings of Bidens, Cnicus, Lactuca, Solidago and Anthemis, the only composite seedlings escaping being those of Arctium. In the case of the other forms, Scrophularia alone succumbed, Abutilon, Malva, Solanum, Datura and Capsella not being visibly affected nor apparently retarded in their growth.

A similar temperature change, brought on gradually (three hours) and continued for three hours, only produced about a 40 per cent. fatality among the composites.

Changes in moisture, either in the soil or in the air, found a ready response in the behavior of the composite seedlings. A diminution of moisture, which would not even produce wilting in the seedlings of other families, would not infrequently prove fatal to those of the composites. The effect of moisture increase was not so readily seen, although there exists under such conditions a tendency on the part of the stem of the seedling to rot near the ground, a tendency apparently shared by Abutilon, and which seems about the only check put upon the increase of this latter form.

As might be expected *direct sunlight* works against the seedlings of composites, as, indeed, against all others, but with a peculiarly fatal effect in these sensitive forms. It has been found necessary in all cases to protect them from the direct sunlight for several days, usually until after the development of the first foliage leaves. Such extreme sensitiveness was rare, if at all present in the other families studied.

FIFTH.—*Cotyledon leaves of nearly related forms closely resemble each other, a resemblance often carried on in the earlier true leaves.*

The cotyledon leaves of Arctium, Cnicus lanceolatus and Cnicus muticus are almost exactly alike. The only dissimilarity observable being that in Arctium the green is a trifle darker than in Cnicus. The resemblance is so exact that I discarded the first germination experiments with Cnicus, supposing that through inadvertence Arctium achenes had been planted. With the appearance of the first true leaves Arctium is plainly marked off from Cnicus, but the two species of Cnicus are not to be separated until the appearance of at least the third foliage leaf. By this statement I mean that I think that at this point I can detect the beginnings of the leaf characters of the forms. The same conditions are found in the Lactucas. Scariola cannot be separated from Canadensis in any of the seedling stages so far as my observations go, indeed, though I carried the seedlings through the development of the seventh foliage leaf I found no marked indication of specific foliar differences. I think, without multiplying instances, that in very many cases supposed relationships between the species of a large genus, and certainly between many genera, might find corroborative evidence in a study of the early foliage of the seedlings.

SIXTH.—*In most cases the highest germination percentages in composites are obtained from surface planting in leaf mold.*

Arctium is the exception to this statement also. By surface sowing upon leaf mold, under the three conditions of moisture, Arctium gave an average germination percentage of 22.2 per cent. In sandy loam, where the achenes were covered by sifting earth over them, the percentage rose to 93.3 per cent. In all other cases, however, the leaf mold gave much the larger per cent. This was especially marked in the case of Cnicus lanceolatus, in which in sandy loam the percentage was 12.5, while in leaf mold the average percentage was 89, rising in one case to 100 per cent. The experiments indicate strongly that successful germination in composites is more closely dependent upon the character of the soil than is the case in the majority of our native plants. In other words, their soil range is so narrow that a slight modification in its character may practically prevent germination of the achenes and thus very effectually limit distribution.

SEVENTH.—*The water content of the soil does not* (so far as is indicated by these experiments), *affect the germination percentage to the degree that might have been expected.*

While differences in the water content of the soil affects the seedlings in a marked way, germination is unaffected under a wide range in water content of the soil. In extreme cases, some forms show marked variations. Arctium, for example, which gives a germination percentage of 93.3 under ordinary soil moisture conditions, falls to 3.3 per cent. in the case of extreme dryness. Cnicus lanceolatus, on the contrary, rises to 100 per cent. in extremely dry soil. In the forms studied the highest percentage of germination is found under moderately moist conditions, and the lowest under extremely dry conditions, save in the case of Cnicus lanceolatus, where the reverse seems to be true. Extreme soil moisture in many cases leads to the moulding of the achenes.

A careful dissection of material used in these experiments showed that there was nothing in the character of the achenes themselves to which this low germination percentage could be attributed. The material was collected with care expressly for these experiments, and dissection demonstrated well formed embryos in more than 80 per cent. of the achenes examined.[2] I am, therefore, led to believe the low germination

[2] The achenes thus examined were taken from the portion of the head indicated in conclusion three, *supra*.

percentages to be due to changes in external conditions, to which, perhaps, the forms are peculiarly responsive. The ease and certainty with which high germination percentages were secured in other families certainly lends support to the view.

The experiments are still in progress, as there are still many points to be worked out in detail. Among them are the effects of varying soil temperatures, of a wider range of soils, of progressive experiments for the determination of resting periods in the various forms, of duration of viability, of the effect of freezing, and others self-suggestive to the experimentalist. Until these are worked out in detail the question as to the causes of the relatively small distribution of any given composite form must remain open. So far as the experiments go they point to this limitation being due in a very large degree:

1. To a low germination percentage, largely due to an extreme sensitiveness on the part of the embryo to external conditions, to which should perhaps be added imperfect pollination, due to causes already given.

2. To an extreme sensitiveness of the seedlings to temperature and moisture changes, either in soil or atmosphere. This necessarily brings about a peculiar sensitiveness to direct sunlight.

When the habits of most of our native composites are considered it will be seen that this extreme sensitiveness in both achene and seedling proves an effectual limitation to their distribution. Other factors than these here emphasized enter, but none are of such general application.

Formalin as a Reagent in Blood Studies. By Ernest I. Kizer.

Among the most common reagents used in the demonstration of blood corpuscle structure, are found osmic acid, salt solutions, picric acid and acetic acid. But all of these cause distortions of the corpuscles, so they are imperfect fixing agents and preservatives. The method of drying blood on the coverslips is seldom successful in the hands of beginners.

Formalin has been found very useful in this connection, both as a fixing agent and as a preservative, because it produces no appreciable dis-

tortion of corpuscles, does not interfere with staining, is easily operated and preserves blood perfectly, at least, for several months.

The method consists of the following steps:

1. Mix one volume of perfectly fresh blood with three volumes of a two per cent. solution of formalin.

2. Allow the mixture to stand at least an hour; then draw a small quantity from the bottom of the vessel with a pipette, by which a drop is transferred to a clean coverslip; spread evenly over the coverslip and allow the liquid to evaporate. The method of pressing the coverslips together, as in sputum analysis, is to be preferred.

3. Pass the coverslips through the flame, films uppermost, in order to cement the corpuscles to the glass.

4. Dip into a five per cent. solution of acetic acid once or twice.

5. Remove the acid with water.

6. Stain. Perhaps the best stain for non-nucleated corpuscles is Gentian violet (a two per cent. solution; time of staining, about two or three minutes). For nucleated forms, contrast stains, as Methyl blue and Gentian violet, or Hæmatoxylin and Eosin, or Methyl green and Safraum, give very good results. Ehrlich's Triple stain may be used for human corpuscles.

7. Wash out excess of stain with water or alcohol as the stain requires.

8. Remove alcohol with clove oil or xylol, and

9. Mount in Canada Balsam.

This method proved very successful in the laboratory of Purdue University, and was used in studying five different forms of corpuscles. They were those of the cat, the ox, the pigeon, the chicken, and man. The human corpuscles were the only ones which resisted the stains, but this difficulty was overcome by the use of a weak solution of acetic acid. Besides making the stains effective, it also clears the films considerably. Although this method may be of no chemical value it promises to be successful for general laboratory purposes.

Species of Diptera Reared in Indiana During the Years 1884 to 1890.

By F. M. Webster.

The following species of Diptera were reared by me while located in Indiana, as Special Agent of the U. S. Dept. Agr., Div. Ent., and are given here as finally determined by Mr. D. W. Coquillett in Bulletin 10, N. S., and Bulletin 7, Technical Series, both of the Division of Entomology.

FAMILY TACHINIDÆ.

Euphorocera claripennis Macq., reared at Lafayette from caterpillars of *Datana contracta* Walk. On one of these larvæ were 213, and on a second 228 eggs of these flies.

Frontina frenchii Will., reared at Lafayette, from caterpillars of *Ichthyura inclusa* Hueb., and also from the larvæ of *Pyrameis cardui* Linn.

FAMILY BOMBYLIIDÆ.

Anthrax hypomelas Macq. This was reared in numbers from the larvæ of *Agrotis herilis*, cutworms, that were excessively abundant in a cornfield near Lafayette, in 1889. See Insect Life, Vol. II, pp. 353–4.

FAMILY OSCINIDÆ.

Meromyza americana Fitch. This occurs throughout the entire State, the larvæ attacking wheat and rye. I reared it from material secured at Oxford, and also from New Harmony.

Chlorops ingrata Will. This species was reared from gall-like swellings on tips of *Muhlenbergia mexicana*. The galls were collected at Oxford, in August, and the adults issued the following May and early June.

Elachiptera longula Loew. This was reared from the stems of *Panicum crus-galli*, within which the larvæ feed, at Oxford, in 1884, and also from fall wheat at Lafayette, in July, 1890, and also from oats, in 1886.

E. nigricornis Loew. and *E. costata* Loew. were also reared with the above in the fall wheat.

E. nigriceps Loew. was reared from *Panicum crus-galli* at Oxford, in September, 1884.

Oscinis trigramma Loew. Reared at Lafayette in July, from volunteer wheat plants. *O. coxendix* Fitch, was reared also with the above.

O. soror Macq., was reared at Oxford, from *Panicum crus-galli*, in October, 1884, and also from the stems of *Poa pratensis*, at Lafayette, in June, 1887.

Oscinis carbonaria Loew., was reared from young wheat plants at Oxford, September, 1884, and from wheat plants at Lafayette, in August, 1886, and again in August, 1888, and in July, 1890, among these last there being also specimens of *O. umbrosa* Loew.

FAMILY AGROMYZIDÆ.

Leucopis nigricornis Egger. Reared from larvæ preying upon *Siphonophora avenæ*, at Vincennes, June 26, 1889, the adults issuing in July, 1889. This is an imported species, as it occurs all over the United States, and has been reared from *Pemphigus* in France.

Ceratomyza dorsalis Loew. Reared from larvæ mining in the leaves of timothy, at Lafayette, in 1888, and also from larvæ mining in the leaf sheaths of wheat.

Agromyza æneiventris Fall. Reared from larvæ burrowing in the stems of white clover, *Trifolium repens*. See Report Commissioner of Agriculture, U. S., 1886, p. 582.

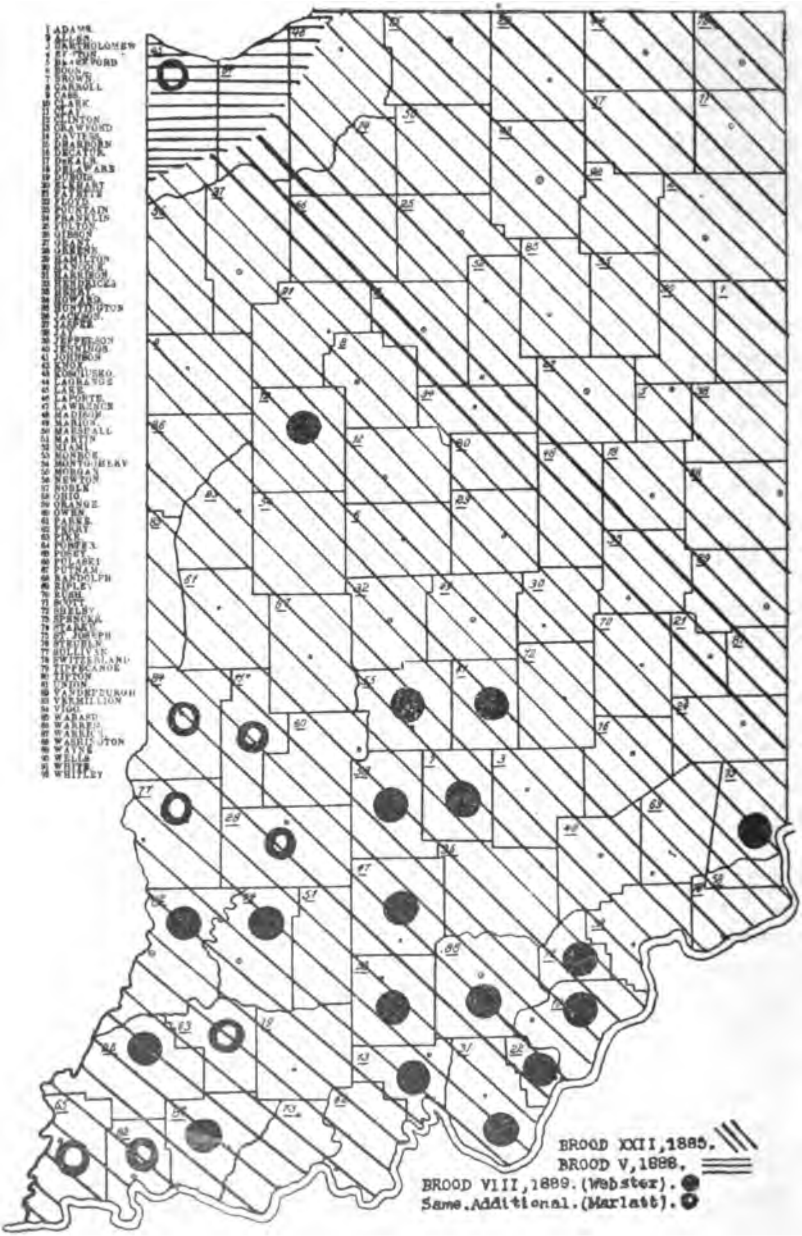
DISTRIBUTION OF BROODS XXII, V AND VIII, OF CICADA SEPTENDECIM, IN INDIANA. BY F. M. WEBSTER.

It was my good fortune, while located at Lafayette, Indiana, during the years 1884-90, as a special agent of the United States Department of Agriculture, Division of Entomology, to have an opportunity of studying the distribution of these three broods of the periodical cicada.

On consulting the accompanying map and explanation thereto, it will be observed that Brood XXII, 1885, covers the entire State, except a small area around the lower extremity of Lake Michigan. This strip of country is much narrower at the Michigan line than it is at the Illinois line, including as it does only the extreme northwest corner of Laporte county, the dividing line between this and Brood V being, here, between the village of Otis and the city of Laporte, crossing the line of Porter county about Wanatah, and passing across Lake county, in the vicinity of Orchard Grove.

This is the strongest of all the broods in Indiana and covers by far the greatest area. Its next recurrence will be in 1902.

Brood V covers only the area over which Brood XXII did not occur and does not, so far as I was able to learn, overlap that brood. It covers a


BROOD XXII, 1885.
BROOD V, 1888.
BROOD VIII, 1889. (Webster).
Same. Additional. (Marlatt).

small portion of Laporte county and the greater portion of Porter and Lake counties, and will reappear next in 1905.

Brood VIII is almost entirely confined to the southern counties and was really very abundant in 1889 only in Harrison county. I have indicated by a dot on the map the localities where I know from personal knowledge the insect occurred, to which localities Mr. C. L. Marlatt, in Bull. 14, N. S., U. S. Dept. Agr., Div. Ent., has added others which I have indicated by a O. The occurrence in Tippecanoe county was at Lafayette, a single female having been found by one of the sons of Dr. E. Test of Purdue University. This is the weakest in point of numbers of the three broods, and will in time become totally extinct, largely, at least, owing to the attacks of the English Sparrow, *Passer domesticus*. It will next appear in 1906.

Some Insects Belonging to the Genus Isosoma, Reared or Captured, in Indiana. By F. M. Webster.

Isosoma grande Riley. This was reared from wheat at Oxford and Lafayette, and was the first proof secured of the presence of a dimorphism, and alternation of generations in *Isosoma tritici*, as it was then known, the latter being now known as *minutum*, the wingless spring and winter generation; and the former as the winged, summer generation, the one having been bred from the eggs of the other by myself.

Isosoma captivum Howard. Captured from *Poa pratensis* at Lafayette. Type.

Isosoma maculatum Howard. Captured with the preceding. Type.

Isosoma tritici Fitch. Reared at Lafayette and elsewhere, and collected on grass at Lafayette.

Eurytomocharis eragrostoidis Howard. Reared at Lafayette from the stems of *Eragrostis poæoides*. Type.

For descriptions of these species, as well as illustrations of them, see Bulletin No. 2, Technical Series, Division of Entomology, U. S. Dept. Agr., by Dr. L. O. Howard.

Lake County Crow Roosts. By T. H. Ball.

[Abstract.]

The main roosting places in these later years, so far as ascertained, are two. One is five miles south of Crown Point, in a pine grove covering an area of about four acres on a large farm well out, in what was once

a wide and open prairie. For several years the crows were there in large numbers, but some three years ago boys shot into the roost and drove them away. They have returned. Mrs. George Schmall estimates the number roosting there at one thousand.

This grove is a "wind breaker," the trees, Scotch and Austrian pine, were set out very thick many years ago. It makes a grand shelter in the winter time. Many of these crows from this pine grove go in a southeasterly direction to find food in the Kankakee marsh region.

The second crow roost of the county is nine miles northwest of Crown Point on both sides of the "Panhandle" railroad, in groves of small oak trees, and one evergreen grove. I visited this locality Tuesday, December 27, 1898. About one mile from it I saw, at 2 p. m., two or three hundred crows feeding in a corn field. Reaching the farm house I learned that two or three pairs of crows selected these groves in 1875. The number of individuals in this colony now may be placed at two thousand. Many of them pass into Illinois to get food, passing in a southwesterly direction over Dyer, on the State line, mornings, sometimes two hundred in a flock.

The Distribution of Blood Sinuses in the Reptilian Head.

By H. L. Bruner.

[Abstract.]

The principal blood sinuses of the reptilian head are the following:

1. The intra-cranial sinuses, which were first described by Rathke[1] in 1839.

2. The nasal sinus, which surrounds the external naris and the nasal vestibule; it was observed and described by Leydig[2] in 1872.

3. The orbital sinus, which lies between the eyeball and its orbit. This sinus was first investigated by Weber[3] in 1877.

The development of the above-mentioned sinuses has been worked out by Grosser and Brezina[4] in the snake (Tropidonotus natrix).

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[1] Rathke: "Entwicklun sgeschichte der Natter (Coluber natrix)." Köenigsberg, 1839.

[2] Leydig: "Die in Deutschland lebenden Arten der Saurier." Tübingen. 1872.

[3] Weber: "Nebenorgane des Auges der Reptilien." Archiv für Naturgeschichte, 43 Jahrg., Band I.

[4] Grosser und Brezina: Morphologisches Jahrbuch., Band 23, 1895.

On the Regulation of the Supply of Blood to the Venous Sinuses of the Head of Reptiles, with Description of a New Sphincter Muscle on the Jugular Vein. By H. L. Bruner.

[Abstract.]

The remarkable development of blood sinuses in the reptilian head has received no explanation at the hands of earlier investigators. The work of the writer shows that the origin of these sinuses is due to periodical constriction of the jugular vein by a ring-like muscle, whose contractions thus lead to an increased blood pressure in the region drained by the vein.

In Phrynosoma this ring-muscle, which is composed of striated fibres, is attached to the lateral end of the ex-occipital bone, beneath which the jugular receives the posterior cerebral vein. Immediately behind the mouth of the latter vein, the ring-muscle embraces the jugular. The muscle occurs also in turtles (Emys) and snakes (Tropidonotus).

According to the observations of the writer on lizards, the distention of the extra-cranial blood sinuses is of great importance at the time of moulting, when the removal of the old epidermis is greatly facilitated by it, particularly in the region of the eyes and nasal openings. Under ordinary circumstances, such distention probably serves to express emotion of various kinds.

The above-mentioned facts furnish a basis for an explanation of the habit of ejecting blood from the eye (orbital sinus), for which Phrynosoma is noted.

For additional details, the writer refers to the paper itself, which will be published in full elsewhere.

Note on the Aberrant Follicles in the Ovary of Cymatogaster.* By George L. Mitchell.

The thickness of the ovarian follicle varies in different vertebrates inversely with the size of the egg. In species containing large eggs the thickness of the follicle *decreases* relatively with the growth of the egg. In the bird and frog it is only in the smaller eggs that the single layer of follicle cells may be distinguished in sections. The rapid growth of the egg soon stretches this layer of cells so that it becomes finally indistin-

*Contributions from the Zoölogical Laboratory of the Indiana University, No. 25.

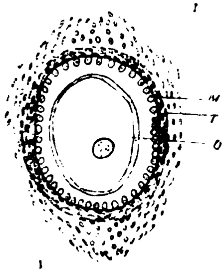
guishable. In species containing relatively small eggs the thickness of the follicle *increases* with the growth of the egg. Examples of this are found in fishes, but the extreme is found in the Graafian follicle of mammals.

The Graafian follicle, whose structure is well known, offers some peculiar features which may be explained in connection with the reduction of the size of the ovum in the mammalian phyllum. Suggestions as to how any why the many layered follicle of higher mammalia has arisen from the single layered follicles of monotremata are furnished by the viviparous fish Cymatogaster. The egg in this species is much below the average in size. It has in fact lost nearly all of its yolk. It is significant, therefore, that among many individuals with normal follicles there are occasionally found individuals containing a small number of many layered follicles. It is to call attention to these and to compare them with the mammalian structures that the present article is prepared.

In order to fully appreciate the conditions, follicles of various mammals and various stages in the same mammal may be briefly mentioned. Poulton has found that in monotremata the follicular epithelium remains a single row of cells.

The follicles of the cat, after moving from the surface toward the deeper parts of the ovary, begin to thicken from the single layered stage to the many layered stage. Fig. 1 represents the single layered stage. Fig. 2 represents the many layered stage in which the follicular cavity is beginning to be formed. The egg in the many layered stage is usually imbedded in the portion of the granulosa nearest the surface of the ovary. The first traces of the follicular cavity are seen in the thicker part of the granulosa. As the egg grows the follicle cells still multiply and the liquor folliculi filling the cavity distends the latter. Fig. 3 shows the follicle with its now nearly ripe egg imbedded in the discus proligerus. This figure represents the typical Graafian follicle.

The follicle of the rabbit differs from that of the cat (Fig. 4). Columns of granulosa cells connect the outer mass of cells with that surrounding the egg. In such follicles as many as four stalks are found in a single section. On examining other sections of the same follicle other stalks may be found so that a single follicle may contain as many as seven of these. In both the cat and rabbit the thickness of the follicular wall is not reduced with the growth of the egg, but rather increases proportionally with the growth. In the opossum both types of follicles of Figs.



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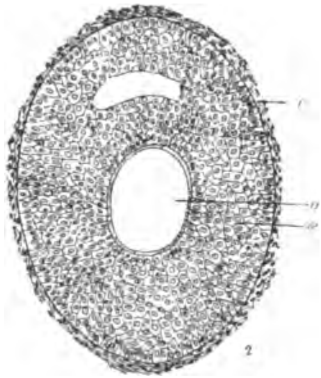

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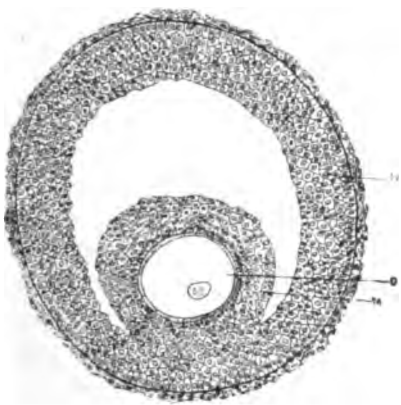

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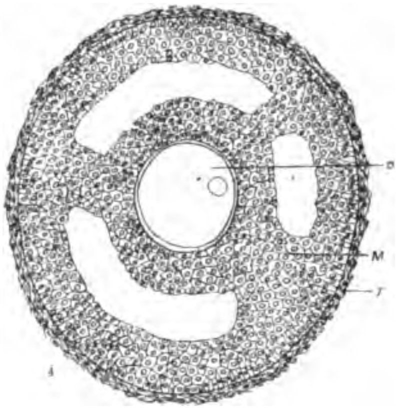

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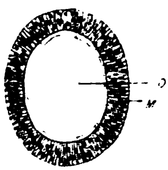

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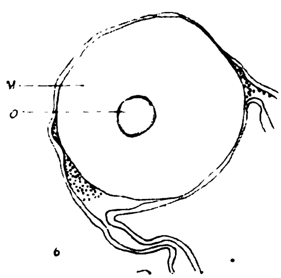

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7

3 and 4 were found. The two varieties were about evenly divided. Of the stalked variety there seemed to be few follicles with more than two or three pronounced cavities.

The normal follicle of Cymatogaster presents no novelties. As the egg ripens the granulosa cells become very high and narrow columnar, but remain in a single series.

As before stated, occasionally there are found, in this species, follicles in which the granulosa is made up of a great many layers of flattened and polyhedral cells. Such a one is represented in Fig. 6. Those cells immediately surrounding the ovum and those next the follicular wall are noticed to be somewhat flattened, while those intermediate are more rounded and polyhedral. The ovaries, which contain such follicles, are comparatively few, but where one such follicle is found, usually two or three more may be found. No indication of follicular cavities has been observed, but the similarity of such follicles to certain stages of the mammalian follicle is at once evident. Compare Fig. 6 with Fig. 2.

If, now, follicular cavities should be formed and filled by an accumulation of follicular fluid we should have conditions similar to those of Figs. 2 and 3.

In oviparous fishes, in batrachians, in birds, in monotremes and in the early stages of mammals, we find the follicles one layered. In the adult stages of marsupials and higher mammals, where the eggs are very small, we find the many layered condition.

The occasional multilayered follicle in the ovary of Cymatogaster, whose egg is but .2-.3 mm. in diameter, seems to bridge the condition found in normally large yolked eggs and the minute eggs of the higher mammals.

The material examined was collected by Dr. C. H. Eigenmann on the coast of California.

EXPLANATION OF FIGURES.

Fig. 1-3. Three stages in the development of the follicle of the cat.

Fig. 4. Follicle of the rabbit.

Fig. 5. Normal mature follicle of Cymatogaster.

Fig. 6. Abnormal follicle of Cymatogaster showing the small egg in the center of a many layered granulosa.

Fig. 7. Part of the granulosa layer of Fig. 6, enlarged.

Material for the Study of the Variation of Pimephales notatus (Rafinesque), in Turkey Lake and in Shoe and Tippecanoe Lakes.* By. J. H. Voris.

As a part of the general plan of the Indiana University Biological Station to study the variation of the same vertebrates in two contiguous lakes belonging to different water systems, I collected during the summer of 1895 a large series of Pimephales notatus in Turkey Lake and the Shoe and Tippecanoe Lakes. Shoe Lake is a small body of water perfectly land locked, but which has but recently become cut off from communication with Tippecanoe Lake. Tippecanoe Lake is a long narrow sheet of water near the head waters of the Tippecanoe River, a tributary of the Wabash. Turkey Lake occupies a corresponding position in the St. Lawrence system. At different points in Turkey Lake 536 specimens were collected in the months of June, July and August. In Tippecanoe, seventy-two specimens were taken, and in Shoe Lake, forty-three.

The species is much more abundant in Turkey Lake than in the other two lakes. Many individuals are found along the shallow rocky shores, and their eggs are found in abundance plastered on the under surface of boards and other submerged objects near the margin of the lake where the water is not more than one or two feet deep. The fry were seen in quiet, warm weather along the shores by the laboratory.

A large number of characters were examined at the beginning of the study, but as many of these, for one reason or another, were found not available for the purposes in hand, the data were finally limited to the number of dorsal and anal rays and to the scales of the lateral line. While this fish has the reputation of being very variable, the characters examined are remarkably constant, and in the number of dorsal and anal rays the species may be said to have reached a stage of stable equilibrium, as the following pages will demonstrate. Since it was not possible in every case to determine absolutely those scales in the lateral line which had and those which had not spores, this character is omitted from the paper.

A miscellaneous lot of 536 specimens from Turkey Lake range in length from 25 mm. to 73 mm. The largest number of individuals of a given length is 37 and these have a length of 47 mm. A curve constructed to show the relative number of specimens of a given length shows that they do not fall into distinct groups of different ages.

*Contributions from the Biological Laboratory of the Indiana University, No. 19.

The dorsal fin has one spine-like ray, eight rays, the last one of which is double, and one very small or rudimentary ray before the spine. The variation from this is very small indeed. Of the 536 specimens from Turkey Lake, 97 per cent. have this number of rays, which may be designated thus: II 8½, the "II" standing for the rudimentary ray and spine, the "8" for the eight rays, and the "½" for the double of the last ray. The average number of rays is 8.0037. The table shows the results obtained.

DORSAL FIN.

No. of Rays.	*No. of Specimens.*	*No. of Rays.*	*No. of Specimens.*
II 8½	519	I 9½	1
II 9½	4	I 7½	1
I 8½	9	II 6	1
II 8	1		

It will be seen from the table that over one-half of those that vary from II 8½ are different only in the absence of the very small rudimentary ray. This is so small and lies so close to the base of the spine that it cannot be seen unless especially looked for. Only five specimens have nine full rays, one with seven and one with six, making in all but six specimens that have a variation of one full ray, and one a variation of two rays from II 8½.

The variation in the anal fin is a little more than in the dorsal, 92.91 per cent. have II 7½ rays. The anal fin has one less ray than the dorsal, and the average for the whole is 7.0037. The greater per cent. of variation in this fin is due to the absence of the rudimentary ray. Only four specimens have one complete ray more, and two one less than II7½. The table shows the results obtained.

ANAL FIN.

No. of Rays.	*No. of Specimens.*	*No. of Rays.*	*No. of Specimens.*
II 7½	498	II 6½	1
II 8½	3	I 6½	1
I 7½	30	I 8½	1
II 7	2		

The following table shows the dorsal and anal fins, together with the number of specimens that each combination contains. It will be seen from this table that there are but three specimens in which there is a variation from the prevailing number in both the dorsal and anal fins. Each of these has the small rudimentary ray absent, and one specimen has one complete ray more than the prevailing number. It seems that

there is no co-ordination in the variation of these two fins. The per cent. of variation above or below the prevailing number in each case is so small that it may be regarded as purely accidental. At least it can be said that this fish in Turkey Lake has reached a stage of stable equilibrium as regards this character.

DORSAL AND ANAL FINS.

Dorsal.	*Anal.*	*No.*	*Dorsal.*	*Anal.*	*No.*
II 8½	II 7½	484	II 9½	II 7½	4
II 8½	I 7½	28	II 6	II 7½	1
I 8½	II 7½	7	II 8½	II 8½	3
I 8½	I 7	2	II 8½	I 6½	1
I 7½	II 7½	1	II 8	II 7½	1
I 9½	I 8½	1	II 8½	II 6¼	1
II 8½	II 7	2			

The dorsal and anal fins of seventy-two specimens from Tippecanoe Lake were examined and the results obtained are shown in the following tables:

DORSAL AND ANAL FINS.

Dorsal Fin.	*No. Specimens.*	*Anal Fin.*	*No. Specimens.*
II 8½	64	II 7½	69
II 9½	3	II 8½	2
II 7½	2	I 7½	1
I 8½	3		

DORSAL AND ANAL FINS COMBINED.

Dorsal Fin.	*Anal Fin.*	*No. Specimens.*	*Dorsal Fin.*	*Anal Fin.*	*No. Specimens.*
II 8½	II 7½	62	I 8½	II 7½	2
II 9½	II 7½	3	I 8½	I 7½	1
II 7½	II 7½	2	II 8½	II 8½	2

A comparison of these tables with the preceding ones shows that the per cent. of variation in the Tippecanoe specimens is much larger than in those from Turkey Lake. However, the number in the one case is not sufficient for a definite conclusion. Leaving out of consideration the small rudimentary ray, which would not be noticed in an ordinary examination, and considering only those cases in which there is a variation of at least one complete ray from the prevailing number, the per cent. in the dorsal fin of the Turkey Lake specimens is 1.3, while in those from Tippecanoe, it is 7. The per cent. of Turkey Lake specimens, that have a variation of at least one ray from the prevailing number in the anal fin, is 1.1, while in the Tippecanoe specimens it is 2.8.

Forty-three specimens from Shoe Lake were examined, and the results obtained are shown in the tables below:

DORSAL AND ANAL FINS.

Dorsal Fin.	*No. Specimens.*	*Anal Fin.*	*No. Specimens.*
II 8½	41	II 7½	40
I 8½	2	I 7½	2
		II 6½	1

DORSAL AND ANAL FINS COMBINED.

Dorsal Fin.	*Anal Fin.*	*No. Specimens.*	*Dorsal Fin.*	*Anal Fin.*	*No. Specimens.*
II 8½	II 7½	38	II 8½	I 7½	2
I 8½	II 7½	2	II 8½	II 7½	1

The number of specimens here is too small to draw any definite conclusions in comparison with the others. It is to be noticed, however, that there is but one case in which the variation from the prevailing number is one complete ray, and that occurs in the anal fin.

The scales in the lateral line of each side of 500 specimens from Turkey Lake were counted. They range from 40 to 48 in number, and the largest number of individuals have 44. The table below shows the number of individuals which have a given number of scales on each side. The striking thing shown by this table is the regularity of the variation on the right side. The largest number of individuals has 44 scales, and there is a range of four both above and below this.

	No. Scales Right Side.	*No. Specimens.*	*No. Scales Left Side.*	*No. Specimens.*
	40	3	40	1
	41	7	41	8
	42	36	42	45
	43	126	43	136
	44	157	44	168
	45	121	45	90
	46	37	46	40
	47	11	47	8
	48	2	48	4
Average	44.01		43.912	

On the right side the variation is nearly symmetrical. On the left side there is not such a marked symmetry. The number of specimens that have fewer than 44 scales on the right side is but one more than those that have more. On the left side, there are 190 that have fewer than 44 scales, and 142 that have more, a difference of 48.

The average deviation, or index of variability for the right is .9369, for the left, .94916.

In the following table every possible combination of scales for the two sides is given with the actual number of specimens for each combination in one column, and the number according to the laws of probability in a parallel column:

Scales. Right.	Scales. Left.	Actual Number of Specimens.	Calculated Number.	Scales. Right.	Scales. Left.	Actual Number of Specimens.	Calculated Number.	Scales. Right.	Scales. Left.	Actual Number of Specimens.	Calculated Number.
40	40	1	0	43	40	0	0	46	40	0	0
40	41	0	0	43	41	3	2	46	41	0	1
40	42	1	0	43	42	15	11	46	42	0	3
40	43	1	1	43	43	56	34	46	43	4	10
40	44	0	1	43	44	37	42	46	44	9	12
40	45	0	1	43	45	13	23	46	45	9	7
40	46	0	0	43	46	2	10	46	46	13	3
40	47	0	0	43	47	0	2	46	47	0	1
40	48	0	0	43	48	0	1	46	48	2	0
41	40	0	0	44	40	0	0	47	40	0	0
41	41	2	0	44	41	1	2	47	41	0	0
41	42	2	1	44	42	14	14	47	42	0	1
41	43	2	2	44	43	37	43	47	43	0	3
41	44	1	2	44	44	69	53	47	44.	2	4
41	45	0	1	44	45	31	28	47	45	2	2
41	46	0	1	44	46	4	13	47	46	3	2
41	47	0	0	44	47	1	3	47	47	3	0
41	48	0	0	44	48	0	1	47	48	1	0
42	40	0	0	45	40	0	0	48	40	0	0
42	41	2	1	45	41	0	2	48	41	0	0
42	42	10	3	45	42	3	11	48	42	0	0
42	43	14	10	45	43	22	33	48	43	0	1
42	44	9	13	45	44	41	41	48	44	0	1
42	45	1	6	45	45	33	22	48	45	1	0
42	46	0	2	45	46	17	10	48	46	1	0
42	47	0	1	45	47	4	2	48	47	0	0
42	48	0	0	45	48	1	1	48	48	0	0

The two columns show that there is a striking deviation from the calculated results, the result of a marked correlation in the variation or tendency to or toward bilateral symmetry. As calculated, the chance association of the same number of scales on the two sides would occur 115 times for all combinations, it actually occurs 187 times. The specimens fall into several definite groups in which the same number of scales on each side forms the center of a group. This is not quite true at the extremes, but is especially marked in the central groups into which the large majority of the specimens fall. There are three specimens in the first group, each of which has 40 scales on the right side. One has 40 scales on the left side, one 42, and one 43. The greatest difference in the number on the two sides is three. There are three specimens in the first group of the calculated column. Each has 40 scales on the right side, one has 43 on the left, one 44 and one 45. The greatest difference in this case is five, and none have the same number on both sides. In the second group of the actual column there are seven specimens, two with 41 scales on each side, two with 41 on the right side and 42 on the left, two with 41 on the right and 43 on the left, and one with 41 on the right and 44 on the left. The greatest difference in the number of scales on the two sides is three. There are seven specimens in the second group of the calculated column. Each has 41 scales on the right side and on the left side one has 42, two have 43, two 44, one 45, and one 46. As in the first group of this column, none have the same number on both sides, and the greatest difference is five. The number of specimens in the fourth group of the actual column is 126. Each has 43 scales on the right side, and on the left three have 41, fifteen 42, fifty-six 43, thirty-seven 44, thirteen 45 and two 46. The largest number of individuals in this group which have the same combination, have the same number of scales on both sides, and the greatest difference in the number on the two sides as in the other cases is three. The calculated column of the same group contains 125 specimens, each of which has 43 scales on the right side. On the left side, two have 41, eleven have 42, thirty-four 43, forty-two 44, twenty-three 45, ten 46, two 47 and one 48. The largest number in this case with the same combination has 43 scales on the right side and 44 on the left, and the greatest difference, as before, is five.

The number of specimens in the same groups of the two columns is the same in most cases, and in no case is there a difference of more than one. This difference is perhaps due to the dropping and adding of frac-

tions. In the calculations fractions of less value than one-half were dropped and those of a value of one-half or more were called one. It will be observed from the groups described—and the same is true of the other groups—that when the number of scales is the same on each side or not more than a difference of one, the actual column exceeds the calculated, and as the difference increases, the calculated column exceeds the actual. A comparison of the corresponding groups in the two columns in every case gives the same results as in those described, all of which demonstrates the tendency to bilateral symmetry or a marked correlation in the variation of the two sides.

PRELIMINARY NOTE UPON THE ARRANGEMENT OF RODS AND CONES IN THE RETINA OF FISHES. BY C. H. EIGENMANN AND GEORGE HANSELL.

[Abstract.]

A variety of fish eyes were examined, and it was found that in most cases the rods and cones are arranged in a regular pattern. This pattern is either that described by Hannover and Ryder for fishes or a slight modification of this pattern.

DEGENERATION IN THE EYES OF THE AMBLYOPSIDÆ, ITS PLAN, PROCESS AND CAUSES. BY CARL H. EIGENMANN.

[Summary only.]

1. There are at least six species of "blind fishes," Amblyopsidæ, inhabiting North America, three with well-developed eyes and three with mere vestiges.

2. The three species with vestigial eyes are descended from generically distinct ancestors with well-developed eyes.

3. These species can be more readily distinguished by the structure of their eyes than by any other characteristic.

4. The most highly-developed eye is much smaller and simpler than the eye of normal-eyed fishes.

5. The structure of their eyes may be represented by the following key to the genera and species.

a. Vitreous body and lens normal, the eye functional. No scleral cartilages. Eye permanently connected with the brain by the optic nerve. Eye muscles normal. No optic fibre layer. Minimum diameter of the eye .700 μ.

Chologaster.

b. Eye in adult more than 1 mm. in longitudinal diameter. Lens over .5 mm. in diameter. Retina very simple, its maximum thickness 835 μ in the old; the outer and inner nuclear layers consisting of a single series of cells each; the ganglionic layer of isolated cells. Maximum thickness of the outer nuclear layer 5 μ; of the inner layer 8 μ .... cornutus

bb. Eye in adult less than 1 mm. in longitudinal diameter. Lens less than .4 mm. Outer nuclear layer composed of at least two layers of cells; the inner nuclear layer of at least three layers of cells, the former at least 10 μ thick, the latter at least 18 μ.

c. Pigment epithelium 65 μ thick in the middle-aged, 102 in the old.

papilliferus.

cc. Pigment 49 μ thick in the middle-aged, 74 in the old; 24–30 per cent. thinner than in papilliferus. Eye smaller .... agassizii.

aa. The eye a vestige, not functional; vitreous body and lens mere vestiges; the eye collapsed, the inner faces of the retina in contact; maximum diameter of eye about 200 μ.

d. No scleral cartilages; no pigment in the pigment epithelium, a minute vitreal cavity; hyaloid membrane with blood vessels. Pupil not closed. Outer nuclear, outer reticular, inner nuclear, inner reticular, ganglionic and pigment epithelial layers differentiated. Cones probably none. No eye muscles. Maximum diameter of eye 180 μ. Eye probably connected with brain throughout life................. .... Typhlichthys.

dd. Scleral cartilages; pigment in the pigment epithelium; vitreal cavity obliterated; no hyaloid membrane. Pupil closed. Some of the eye muscles developed. No outer reticular layer. Outer and inner nuclear layers merged into one. Eye in adult not connected with the brain.

e. Pigment epithelium well developed; cones well developed; ganglionic cells forming a funnel-shaped mass through the center of the eye. Pigmental epithelium over the front of the eye without pigment. Maximum diameter of eye about 200 μ .... Amblyopsis.

ee. Pigment epithelium developed on distal face of the eye, rarely over the sides and back. No cones. Nuclear layers mere vestiges; the ganglionic layer restricted to the anterior face of the eye just within the pigmented epithelium. Maximum diameter of the eye about 85 μ .... Troglichthys.

6. The structure of the vestigial eyes differs much in different individuals.

7. The eye of Chologaster is an eye symmetrically reduced from a larger normal fish eye.

8. The retina in Chologaster is the first structure that was simplified.

9. Later the lens, and especially the vitreous body, degenerated more rapidly than the retina.

10. The eye of Typhlichthys has degenerated along a different line from that of Amblyopsis, its pigmented epithelium having been most profoundly affected.

11. The eye muscles have disappeared in Typhlichthys.

12. Troglichthys shows that the steps in the degeneration of the muscles were in the direction of lengthening their attaching tendons, finally replacing the muscles with strands of connective fibres.

13. The scleral cartilages have not kept pace in their degeneration with the active structures of the eye.

14. The lens in the blind species is, for the most part, a small group of cells without fibres.

15. The proportional degeneration of the layers of the retina is shown in diagram j.

16. With advancing age the eye of Amblyopsis undergoes a distinct ontogenic degeneration from the mature structure.

17. The phyletic degeneration does not follow the reverse order of development. None of the adult degenerate eyes resemble stages of past (phyletic) adult conditions.

18. The degenerate eyes do not owe their structure to a cessation of development at any past ontogenic stage, *i. e.*, at any stage passed through in the development of a normal life.

19. Cessation in development occurs only in the reduction of the number of cell generations produced to form the eye not in cessation of morphogenic processes.

20. In some cases (Typhlichthys) there is a retardation in the rate of development, the permanent condition being reached later in life than is usual in fishes. (It is possible that the pigment of the pigment epithelium never comes to develop at all. It is, however, impossible to assert this until the embryos of this species are examined. It is possible that the pigment degenerates before the stages are reached that I have examined.)

21. The degenerate condition of the eye appears in the embryo. The crowding back has followed the law of tachygenesis.

22. The conditions in the eyes of the Amblyopsidæ can only be explained as the result of the transmission of disuse effect.

The Ear and Hearing of the Blind-fishes.* By Carl H. Eigenmann and Albert C. Yoder.

The following words of Prof. Cope are frequently quoted: "They (Amblyopsis) are unconscious of the presence of an enemy, except through the medium of hearing. This sense, however, is evidently very acute; for at any noise they turn suddenly downward and hide beneath stones, etc., on the bottom."

Miss Hoppin (Garman, 1889) was the first to cast doubt on this statement. She failed to get any response from Troglichthys as long as noises only were resorted to.

Our own observations (Proc. Brit. Ass. A. Science, Toronto Meeting) on Amblyopsis confirm those of Miss Hoppin on Troglichthys. No noises produced had any effect on Amblyopsis. Whistles, tuning forks, clapping of hands, shouting in the reverberating caves, were alike disregarded. Not one observation was made that would indicate that these fishes can hear. This does not imply that the auditory organs of this fish are not fully developed. Nor is it an indication that the auditory function of this fish is degenerate, for Kreidl and Lee have both shown that fishes as a class are unable to hear. Kreidl's observations were made on fishes which were blinded or from which the operator was hidden by some contrivance. Neither of these devices need be resorted to with the present species.

Anatomically considered, the ear of Amblyopsis is normal. Numbers of ears together with the brains have been dissected out. These were treated either with Flemming's strong solution or with Hermann's fluid, either of which stained the nerve matter black.

In the first place, the three semi-circular canals are present and each has its ampulla fully developed. The three ampullæ and the sinus utriculus superior communicate with the utriculus in front, behind, and above Below, the utriculus communicates with the sacculus, which terminates posteriorly in an appendage, the lagena.

The three ear bones are present, one in the recessus utriculi, one (the largest) in the sacculus, and the other in the lagena.

The auditory nerve divides into two branches, the ramus anterior and the ramus posterior. The ramus anterior divides into three branches—the ramulus ampullæ anterioris, which extends to the anterior ampulla;

*Contributions from the Zoölogical Laboratory of the Indiana University, No. 30.

the ramulus ampullæ externæ, which extends to the external ampulla; the ramulus recessus utriculi, which extends to the recessus utriculi. The ramus posterior gives off a heavy branch, the ramulus sacculi, which extends to the sacculus. The rest of the ramus posterior divides into the ramulus lagenæ, which extends to the lagena; and the ramulus ampulla posterioris, which extends to the posterior ampulla. Another branch, the ramulus neglectus, which is normally given off where the ramus posterior divides into the ramulus ampulla posterioris and ramulus lagenæ, has not been identified.

The normal fish ear has seven auditory spots—the macula acusticus recessus utriculi, three cristæ acusticus ampullarum, macula acusticus cacculi, papilla acusticus lagenæ, and the macula acusticus neglecta. In Amblyopsis all of these auditory spots are present:

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EXPLANATION OF FIGURES.

The lettering is uniform throughout and in the main that used by Retzius in "Das Gehörorgan der Wirbelthiere."

ca—Canalis anterior.

ce—Canalis externus.

cp—Canalis posterior.

s—Sacculus.

u—Utriculus.

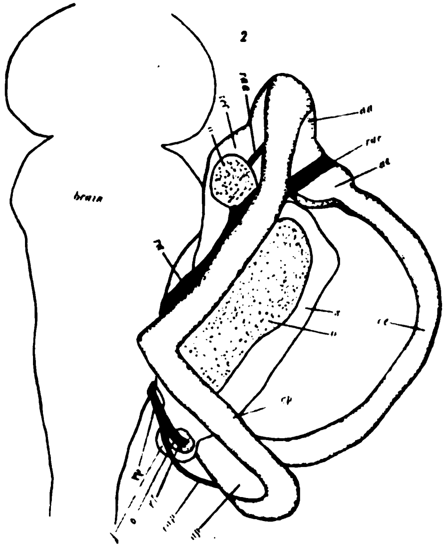
rec—Recessus utriculi.

ss—Sinus utriculi superior.

cus—Canalis utriculo-saccularis.

l—Lagena.

2



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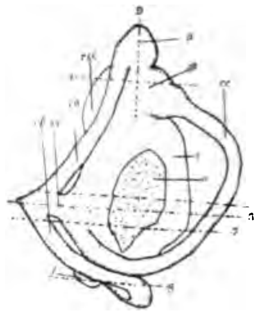

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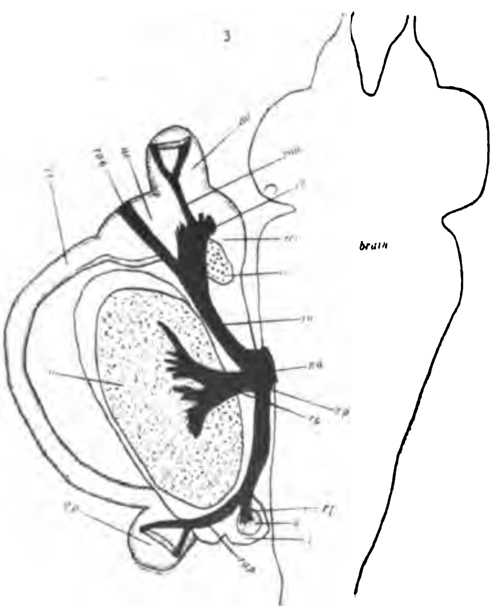

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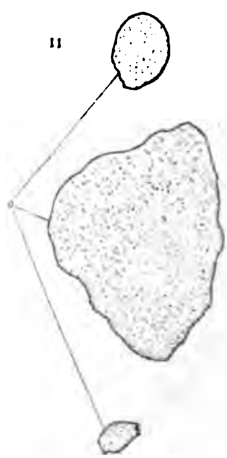

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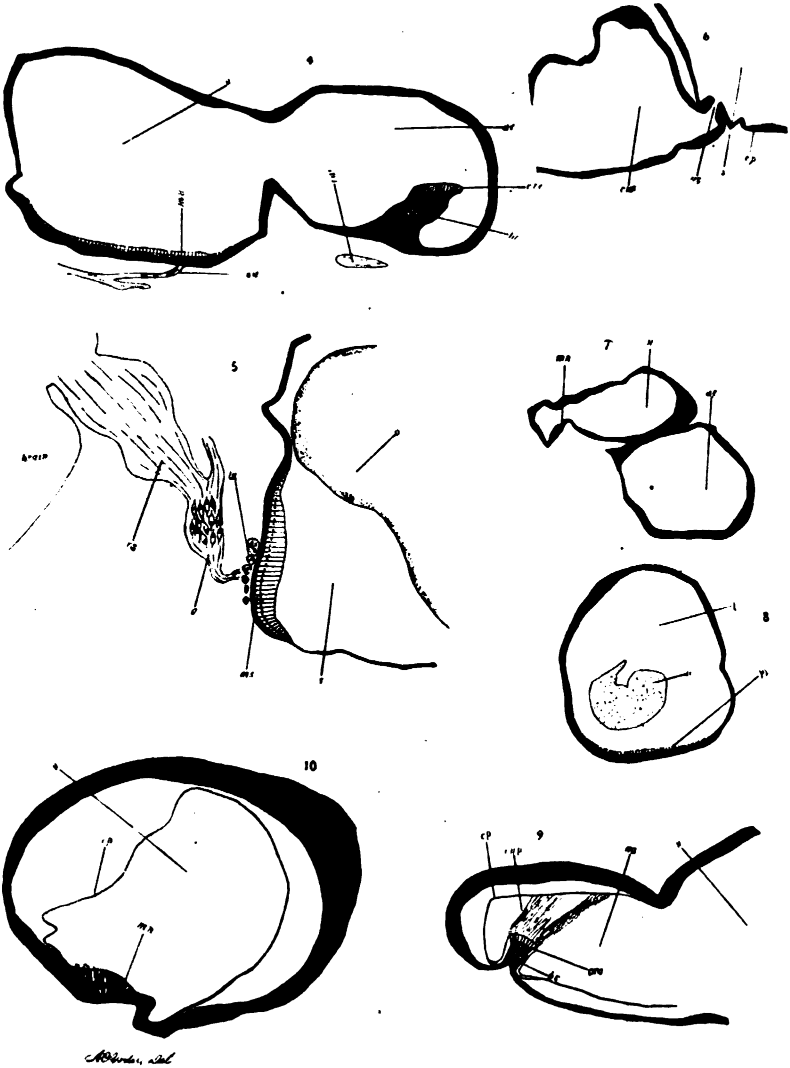


aa—Ampulla anterior.
ae—Ampulla externa.
ap—Ampulla posterior.
cra—Crista acustica ampullæ anterioris.
cre—Crista acustica ampullæ externæ..
mu—Macula acustica recessus utriculi.
ms—Macula acustica sacculi.
pl—Papilla acustica lagenæ.
mn—Macula acustica neglecta.
na—Nervus acusticus.
ra—Ramus anterior.
rp—Ramus posterior.
raa—Ramulus ampullæ anterioris.
rae—Ramulus ampullæ externæ.
rs—Ramulus sacculi.
rl—Ramulus lagenæ.
rap—Ramulus ampullæ posterioris.
ov—Oval opening into sacculus from the canalis utriculi-saccularis.
bv—Blood-vessel.
cap—Capula terminalis.
ep—Epithelial lining.
g—Ganglion cells.
o—Otolith.

Fig. 1. Right ear. Viewed from the exterior and above. The dotted lines show the planes of sections. ×12.

Fig. 2. Brain and right ear. Dorsal view. The nerves are shown black. The fibers for the most part are under the ear, but they were seen through the membranous parts. ×21.

Fig. 3. Brain and right ear. Ventral view. ×23.

Fig. 4. Cross section of utriculus and the crista in the external canal. ×195.

Fig. 5. Part of a vertical section through the brain, ramulus sacculi, and sacculi. The course of the ramulus sacculi is shown here. ×195.

Fig. 6. Section showing canalis utriculo-saccularis and the oval opening through which there is communication between the utriculus and the sacculus. The sections were made parallel to the sinus utriculo-superior. ×195.

Fig. 7. Utriculus and canalis externus. Cross section showing the macula neglecta. ×195.

Fig. 8. Lagena. Cross section showing the capilla acustica. ×195.

Fig. 9. Ampulla anterior. Longitudinal section. Cross section of crista. ×195.

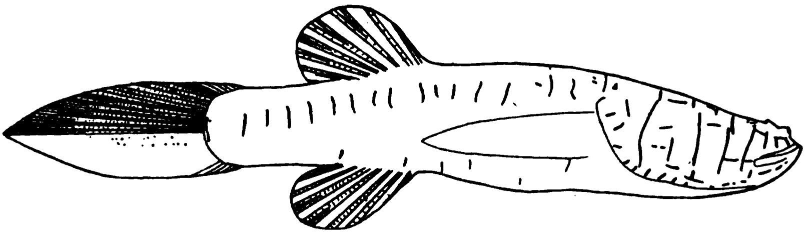
Fig. 10. Utriculus. Cross section showing the macula neglecta. ×(1/6 obj. 2 in oc).

Fig. 11. The three otoliths drawn to the same magnification. The largest belongs to the sacculus; the smallest to the lagena, and the other to the recessus utriculi. ×23.

A Case of Convergence.* By Carl H. Eigenmann.

In 1859 Girard (Proc. Acad. Nat. Sc., Phila., p. 62) described a small blind fish, *Typhlichthys subterraneus* from Bowling Green, Ky. This species has since been found to be abundant in the subterranean waters east of the Mississippi and south of the Ohio.

In 1889 Garman (Bull. Mus. Comp. Zool. XVII, No. 6) gave an account of a blind fish from some caves in Missouri. Mr. Garman says: "Compared with specimens from Kentucky and Tennessee, they agree so exactly as to raise the question whether the species was not originated in



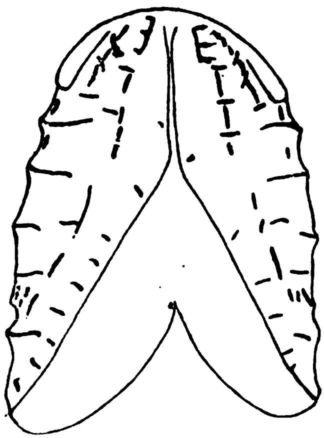
one of the localities and thence distributed to the others. * * * There is no doubt that the representatives of *Typhlichthys subterraneus* in the various caves were derived from a single common ancestral species. The doubts concern only the probability of the existence of three or more lines

*Contributions from the Zoölogical Department of the Indiana University, No. 27.

of development in as many different locations, starting from the same species and leading to such practical identity of result."

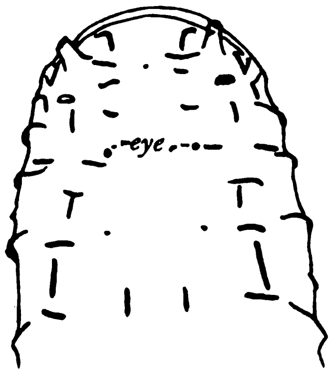
Ably arguing the case from the data on hand, Garman came to the conclusion "that these blind fishes originated in a particular locality, and have been and are being distributed among the caves throughout the valley" (of the Mississippi).

Two of the specimens from Missouri served Kohl ("Rudimentäre Wirbelthieraugen," 1892) for his account of the eyes of North American



blind fishes. At my request Mr. Garman sent me two of the Missouri specimens. He urged me at the same time to make a more extensive comparison between them and the Mammoth cave specimens. A comparison of the eyes of specimens from the two localities not only proved that they represented distinct species, but that they are of separate origin. An announcement of the species without further description was published (Proc. Ind. Acad. Sci. for 1897, p. 231, 1898). The species was "named *rosæ* for the rediscoverer of the California *Typhlogobius*, a pioneer in the study of biology among women, Mrs. Rosa Smith Eigenmann." In the spring of 1897 I visited various caves in Missouri to secure additional material of what was recognized as in many ways the most interesting member of the North American fauna. No specimens were secured, but a liberal number of bottles of alcohol and formalin were scattered over the country. During this fall, through a grant from the Elizabeth Thomp-

son Science Fund and through the courtesy of the officers of the Monon, the L. E. and St. L. and the Frisco R. R. lines, I was enabled to visit the cave region of Missouri again. This time I visited nine caves and secured eight specimens. I have since received an additional number from a correspondent. From information gathered it would seem that this species (or similar ones) has a wide distribution in the subterranean water of the southern half of Missouri and northern Arkansas, probably also the eastern part of Kansas.



On the surface the specimens very cosely resemble *Typhlichthys subterraneus* from Mammoth Cave, differing slightly in the proportion and in the pectoral and caudal fins. These fins are longer in *rosæ*. It is, however, quite evident from a study of their eyes that we have to deal here with a case of convergence of two very distinct forms. They have converged because of the similarity of their environment and especially owing to the absence of those elements in their environment that lead to external protective adaptations. The details of the structure of the eyes of all the members of the Amblyopsidæ will be published shortly, and I need call attention here only to the structures that warrant the conclusion that the cis and transmississippi forms of blind fishes without ventral fins are of distinct origin. The blind fish *Amblyopsis* may be left out of consideration, since it is the only member of the family that possesses ventral fins. Otherwise, it would be difficult to distinguish specimens of similar size of this species from either *subterraneus* or *rosæ*.

The eye of *T. subterraneus* is surrounded by a very thin layer of tissue representing the sclera and choroid. The two layers are not separable. In this respect it approaches the condition in the epigean-eyed member of the family *Chologaster*. For other reasons that need not be given here, it is quite certain that *Typhlichthys* is the descendant of a *Chologaster*. The intensity of coloration and the structure of the eye are the chief points of difference. The eye of *rosæ* is but about one-third the diameter of that of *subterraneus*, measuring .06 mm. or thereabout. It is the most degenerate as distinguished from undeveloped vertebrate eye. The point of importance in the present instance is the presence of comparatively enormous scleral cartilages.* These have not degenerated in proportion to the degeneration of the eye and in some cases are several times as long as the eye, projecting far beyond it or are puckered to make their disproportionate size fit the vanishing eye. The species is unquestionably descended from a species with well-developed scleral cartilages, for it is not conceivable that the sclera as found in *Chologaster* could, by any freak or chance, give rise during degeneration to scleral cartilages, and if it did, they would not develop several sizes too large for the eye. At present no known epigean species of the Amblyopsidæ possesses scleral cartilages. The ancestry of *rosæ* is hence known. *Amblyopsis* possesses scleral cartilages and the eye of *rosæ* passed through a condition similar to that possessed by *Amblyopsis*, but the latter species has ventral fins and is hence ruled out as a possible ancestor of *rosæ*. The epigean ancestry of *Amblyopsis* is also unknown. The ancestry of *Typhlichthys* being quite distinct from that of *rosæ*, the latter species may be referred to a new generis named *Troglichthys*.

Judging from the degree of degeneration of the eye *Troglichthys* has lived in caves and done without the use of its eyes longer than any other known vertebrate. (*Ipnops* being a deep-sea form is not considered.) More than this, *rosæ* is probably the oldest resident in the region it inhabits.

Since the specimens kindly sent by Mr. Garman, in the course of examination, have been reduced to sections, the specimens now in my possession, together with a few sent to the British Museum, all having come from the same cave, may be considered typical.

In addition to the acknowledgments made before I wish also to thank the officers of the Louisville and Nashville R. R. for transportation to Mammoth Cave. I must especially express my appreciation of the assist-

* Kohl mistook the nature of these structures, as he did of every other connected with these eyes, except the lens and ganglionic cells.

ance rendered me by Mr. William McDoel, General Manager of the Monon, in enabling me to make explorations in the numerous caves of the Lost River region along his line and to visit caves at greater distances. Mr. H. C. Ganter, the manager of the Mammoth Cave Hotel, not only granted me leave to collect in the cave, but did everything possible to make my trip to this cave successful.

Chologaster agassizii and Its Eyes. By Carl H. Eigenmann.

[Abstract.]

Chologaster agassizii has heretofore been known from the type specimen only. This came from a well at Lebanon, Tennessee. I have heard of other specimens, but neither persuasion nor a liberal cash promise was able to bring one of these specimens. Five specimens were recently caught by me.

Chologaster agassizii possesses this peculiar interest: The Amblyopsidæ, evidently the wreck of an ancient numerous family, are now represented by Chologaster with well-developed eyes, and the various blind fishes with greatly degenerate eyes. Of Chologaster there are three known species. One of these lives in the streams of the Atlantic slope and does not concern us. The other, Ch. papilliferus, lives in springs in southwestern Illinois, while the third, Ch. agassizii, lives altogether in subterranean streams. I wanted Ch. agassizii to compare its eyes with those of Ch. papilliferus. The interest is heightened by the fact that the two species are very similar, the eye of agassizii is, however, very much smaller and will, when examined, give us one of the steps of degeneration through which this structure passes.

The Eye of Typhlomolge from the Artesian Wells of San Marcos, Texas. By C. H. Eigenmann.

[Abstract.]

The eye of Typhlomolge has lost the lens and for the most part the vitreous body. The eye has, as a result, collapsed. The pupil is still open in the young but becomes closed in the adult, and in its region the pigment of the iris becomes much thicker than the pigmented layer at the back of the retina.

The Eyes of Typhlotriton Spelæus.* By Carl H. Eigenmann and W. A. Denny.

[Abstract.]

Typhlotriton was discovered in Rock House Cave, Barrie County, Mo., by Mr. F. A. Sampson, in July, 1891. The specimen was described by Stejneger in the Proc. U. S. Nat. Mus., Vol. XV, p. 115. This is the only mention made of this salamander in literature.

In the spring of 1897, I visited Rock House Cave and secured a number of larvae which Stejneger pronounced the larvae of his Typhlotriton. I was informed by Mr. E. A. Schultzè, a member of this academy, that he had seen this salamander in the underground passage to Blondis Throne room in Marble Cave, Mo.

In September of 1898 I visited this cave and secured four adults and three larvae of the Typhlotriton. A large number of larvae were obtained from Rock House Cave. Those from Rock House Cave had lived in the light, but it is scarcely supposable that those from Marble Cave had ever been affected by the light. In the caves both larvae and adults are found under stones in and out of the water. Occasionally one is seen lying on the bottom of a pool.

In the aquarium the larvae creep into or under anything available. A rubber tube served as a hiding place. The rubber tube admitting water to the acquarium is sometimes occupied by several (at one time seven) during a temporary cessation of the flow of water. A wire screen sloping from the bottom of the aquarium forms the most popular collecting place of the larvae. They collect beneath this, although it is no protection from the light. The eye does not protrude in the larva but it does in the adult. It is retracted after death, however, so that preserved specimens will not give a correct impression of the real condition.

The following are a series of measurements on the larvae of Typhlotriton.

	Rock House Cave.	*Rock House Cave.*	*Marble Cave.*
	mm.	*mm.*	*mm.*
Specimen (length)	54	78	88
Size of pupil	.432	.640	.....
Length of eye	1.30	1.50	1.60
From optic nerve to front of lens	.80	1.20	......
Vertical diameter	.....	1.248	1.28

* Contributions from the Zoölogical Laboratory of the Indiana University, No. 31.

An adult and a larva taken from Marble Cave were sectioned in the usual manner. The lens and iris in both were normal. The only difference in the histological structure of the eye, when compared with the normal salamander (Amblystoma jeffersonianum), is found in the retina.

In the larvae all the layers of the retina are well developed. The ganglionic layer is much thicker than that of the Amblystoma, having many rows of cells instead of one or two. All the other layers are normally present, the rod and cone layer being well developed. The retina in the larva is much thicker than in the adult. In the adult the rods and cones have disappeared, there being only an occasional process from the outer nuclei.

In all the sections thus far studied we have been unable to detect the slightest indication of an outer molecular layer in the adult, while in the larva this layer is normally developed. The ganglionic layer is thicker in the larva than in the adult. In this respect the adult approaches the normal more than the larva does. The Müllerian fibres are profusely present in both larva and adult.

SUMMARY.

1. The larval retina approaches the normal (Amblystoma) more than the adult. The only apparent difference is a thickening of the ganglionic layer.
2. The retina is thicker in larva than in adult.
3. All the layers are present in the retina of the larva, while in the adult the rods and cones and the outer molecular layer have not been made out; the inner molecular layer is thinner.
4. The ganglionic layer is thicker in larvae than in adult.

THE BLIND RAT OF MAMMOTH CAVE.* BY CARL H. EIGENMANN AND JAMES ROLLIN SLONAKER.

HABITS AND HABITAT, BY CARL H. EIGENMANN. NO. 32.

In his origin of species, sixth edition, Vol. I, page 171, Darwin says that the eyes of Neotoma of Mammoth Cave are "lustrous and of large size; and these animals, as I am informed by Prof. Silliman, after having been exposed for about a month to a graduated light, acquired a dim per-

*Contribution from the Zoölogical Laboratory of the Indiana University.

ception of objects." The cave rat, Neotoma, is still abundant in Mammoth Cave. It is found in the rotunda near the entrance of the cave and in the more distant parts of the cave. Its tracks are numerous, and in places little paths have been made by the rats where they run backward and forward along ledges of rock. Since, however, a track once made in a cave remains unchanged by wind or weather, the abundance of rats, as judged by their tracks, may be misleading. A number of traps were set in the rotunda. During three days one trap was sprung and one had the bait removed. No rats were caught in the traps and none were caught alive. I discovered one rat rolling a mouse trap about which was too small for it to enter. When approached with a light the rat turned about

Fig. 1. Mammoth Cave Rat.

Fig. 2. Common Gray Rat.

and stared at the light. It then ran to a pile of rocks but did not attempt to hide; instead the rat ran to one end of the pile, then along the top back to where I stood, when it stopped and again stared at the light. An attempt to catch the rat sent it running back and forth along the ledges of rock at the side of the cave. Finally the rat came to the ground again, and despairing of catching it alive it was killed. Its eyes appeared to be large and protruding very much as in the common rat. Without question the rat noticed the light. It had no hesitation in running from place to place. The manager of the Mammoth Cave Hotel, Mr. H. C. Ganter, later caught four rats which he sent by express. Only one arrived alive; one had been partly eaten by the others. The living one is now caged. It is quite gentle. It permits itself to be stroked. Occasionally it pushes an object away with a sideward motion of the fore foot. If

provoked it snaps at the object. During the daylight it sits quietly in a nest it has formed for itself of cotton batting, which it pulled into a fluffy mass. At night it is frequently moving about in its cage. Turning on an electric light near its face always produces a twitching of the eyelids; so there can be no doubt that the light is perceived. An object held some distance from the cage either on one side or another is always perceived, but just how precise its vision is has not been determined. Its hearing is acute.

THE EYE. BY J. R. SLONAKER.

As far as I have been able to ascertain, little or no microscopical investigation has been made on the eye of the Mammoth Cave rat.

A glance at a photograph of a cave rat (Fig. 1) shows that the eye is as prominent as in the common gray rat (Fig. 2).

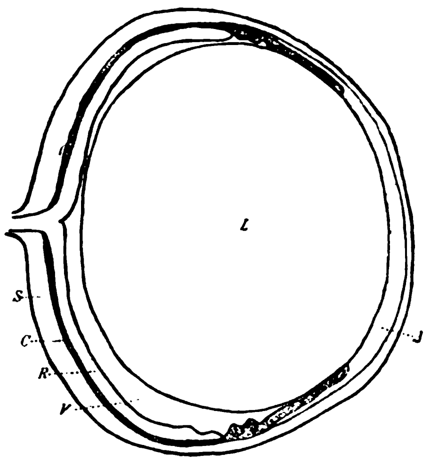


Fig. 3. Mammoth Cave Rat (× 8).

If the elements of the retina have the same function in the cave rat as in other rats, we may approach closely to their power of sight under favorable conditions, by comparing their retina with that of those living in the light. For such a preliminary comparison I have chosen the nearest allied form which I could readily get, the common gray rat (Mus decumanus).

The eye of the cave rat is, if anything, larger in proportion to its body weight than that of our gray rat (Figs. 3 and 4). The lens is in each case enormously large in proportion to the eye, so large, in fact, that very little space is left for the aqueous and vitreous humors. The pupil is capable of very wide dilation, as is true with most nocturnal animals.

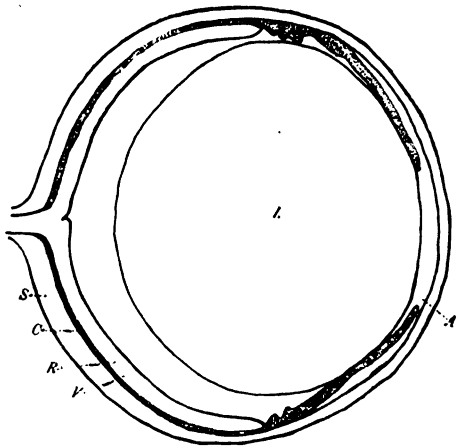


Fig. 4. Common Gray Rat (× 8).

A. **Aqueous Chamber.**
C. **Choroid and Pigment Layers.**
L. **Lens.**
R. **Retina.**
S. **Sclerotic.**
V. **Vitreous Chamber.**

The head of the cave rat, being more rounded and less pointed than that of the gray rat, permits of a slightly deeper eye-socket. However, these two rats resemble each other in their "pop-eyed" appearance when frightened.

A microscopical comparison of the retina also shows little difference. Bits of retina from corresponding parts of the eye of a cave rat and a gray rat were hardened by the same process, sectioned the same thickness and stained alike, so that the sections are directly comparable. Fig. 5 represents semi-diagrammatic camera drawings of two such sections.

At a glance one can see that there is very little difference excepting in the thickness of the retina, that of the cave rat being thicker. This difference, however, may be due to the fact that Fig. 5a, is from a very large cave rat, while Fig. 5b is from a half-grown gray rat. The thickness, however, bears about the same ratio to the size of the eye in each

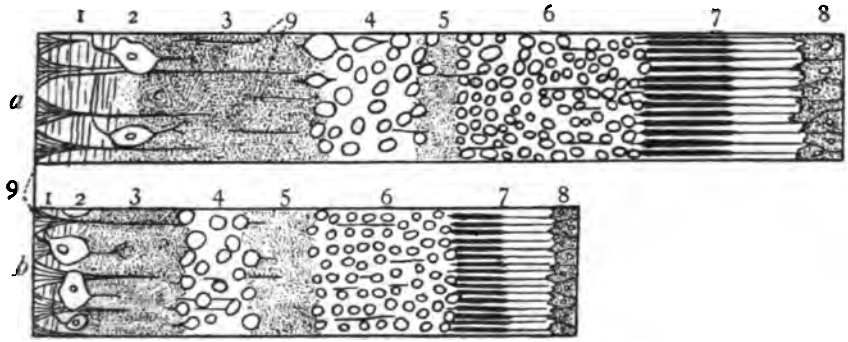


Fig. 5. Semi-diagrammatic camera drawings (× 265).

a. Mammoth Cave Rat.
b. Common Gray Rat.
1. Nerve Fibre Layer.
2. Nerve Cell Layer.
3. Inner Molecular Layer.
4. Inner Nuclear Layer.
5. Outer Molecular Layer.
6. Outer Nuclear Layer.
7. Rod and Cone Layer.
8. Pigment Layer.
9. Supporting Fibres of Müller.

case. This greater thickness is largely due to an increase in the size of the cells of corresponding layers of the retina in the cave rat. Only a single instance need be given. The rod and cone layer of the cave rat is composed of decidedly longer and larger elements than the same layer of the common rat. But with the exceptions of these minor differences in the thickness of the layers and in the size of the cells, the two retinae are nearly alike.

Basing our conclusions on the histological structure of the eye, we may infer that the cave rat has the power of seeing as distinctly as the common gray rat.

A NEMATOID WORM IN AN EGG. BY DANIEL J. TROYER.

THE GEOLOGIC RELATIONS OF SOME ST. LOUIS GROUP CAVES AND SINKHOLES. BY M. N. ELROD, M. D.

Before discussing the geologic relations of the caves, sinkholes and subterranean channels of St. Louis limestone to each other and to the strata in which they occur, it will be necessary to define the limits of that formation in Indiana. The Warsaw bed, as exposed at Spergen Hill and elsewhere, is recognized as the equivalent of the Bedford oölitic limestone, and the lowest member of the St. Louis. The fossils found in it are abundant and characteristic, and its lithologic peculiarities obvious. But the upper limits of the group are not so well settled. When Prof. James Hall first fully defined the Kaskaskia group, as seen on the banks of the Mississippi River, he included as its lowest member a stratum of sandstone. In Indiana the first sandstone stratum above the St. Louis has been recognized as forming a part, at least, of the Kaskaskia group, but not always as its lowest limit. The classification of Prof. Hall* was first applied to the geologic formations of Indiana by ex-State Geologist E. T. Cox, in 1872, in a report on the geology of Perry County,† in which he made the first sandstone above the St. Louis the base of the Kaskaskia group, and by the law of priority, his identification should be recognized unless there is sufficient reason for a change. Since that time the dividing line has been placed at a lower level; one observer finding it at a small coal seam in the limestone strata;‡ others at the top of the upper fossiliferous chert member of the St. Louis;¶ and others have included with the Kaskaskia extensive strata of limestone under the sandstone, without indicating by a section or otherwise where the one terminated and the other began.§ Much of this confusion has grown out of an effort to limit the upper St. Louis group to such strata only as contain *Lithostrotion canadense* Castelnau and *L. proliferum* Hall, characteristic fossils

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* Hall's Geol. of Iowa, pt. 1, p. 109, 1858.

† Geol. Sur. Ind., 1872, pp. 76, 77.

‡ Geol. Sur. Ind., 1873, p. 365; 1878, pp. 305, 425.

¶ Geol. Sur. Ind., 1875, pp. 207, 216.

§ Geol. Sur. Ind. 1895, pp. 231, 232; 1896, p. 300.

of the undisputed St. Louis formations. But if this palæontologic test is to be applied to the upper strata it is hard to understand how the Bedford oölitic can be retained as a member, as these fossils are not found in it.

At the top of the sinkhole division of the St. Louis in Lawrence, Orange and Washington Counties, and doubtless in Harrison County, there is a constant stratum of chert from ten to twenty inches thick. Above this chert other thin flinty layers may be found, but so far as known, they are not fossiliferous. The heavy chert may be seen in place at Paoli in the north bank of Lick Creek, at the Wesley Chapel Gulf, and on Lost River near Orangeville. Because of its frequent occurrence on that stream is is suggested that it be named the Lost River chert. It is generally highly fossiliferous, very rich in bryozoans and occasionally oölitic. Above, and conformable with it, there is found from sixty to ninety feet of massive, close-textured limestone, slightly broken at the top by beds of calcareous shale, and near the middle by included chert nodules; generally the ground mass is lithographic. This stratum includes all the rocks found below the first Kaskaskia sandstone and above the Lost River chert, and as it is well exposed at that place it is proposed that it be known as the Paoli limestone. On palæontologic grounds, which cannot be presented in full here, the Paoli limestone is assigned to the St. Louis group. The fossils that occur in it, at many places in abundance, are of the same species as the more common forms found at Spergen Hill. The chemical composition and general appearance is such as to clearly show that it is a repetition of the strata exposed below it. Its lithologic characteristics are obvious, and the residual clay resulting from its disintegration presents the same physical appearance as the red, plastic and impervious clay of the undoubted St. Louis formations.

Mr. C. E. Siebenthal has proposed the name Mitchell limestone for "A series of impure limestones, calcareous shales and fossiliferous limestones" overlying the Bedford oölitic limestone, and says: "The topographic *tendency* of the Mitchell limestone expresses itself in plateaus perforated at short intervals by sinkholes."* As he does not define the upper limits of his "Mitchell limestone" it is suggested that his definition be amended to include all the St. Louis limestone below the Lost River chert and above the Bedford oölitic. Its upper and middle strata are largely

* Geol. Sur. Ind., 1896, pp. 298, 299.

lithographic, and quite often include chert nodules and plates. The upper members are the equivalent of the true "Cavernous limestone," and the "Barrens." In the lower portion sinks are not so common, and the strata become argillaceous and in many places hydraulic.

A section through Orange and Washington counties will show the following succession of formations:

Kaskaskia, sandstone—	
St. Louis.	*Ft.*
Paoli limestone, calcareous shale and lithographic limestone	90
Lost River chert, fossiliferous	1
Mitchell limestone, lithographic limestone and calcareous shale with chert inclusions, the lower portion argillaceous and hydraulic	160
Bedford oölitic limestone—Warsaw	60
Keokuk.	
Total	311

The caves of the impure, lower Mitchell limestone stratum are peculiar in that they are only incidentally connected with surface sinks, and generally have streams of water flowing from the external opening. The mouth is usually found above the oölitic limestone in the side hill of a deep valley. The interior shows the erosive effects of running water, the passage diminishes in size as it recedes from the mouth, and its side branches are low, narrow reproductions of the main cave. To this class belong Donnehue's, Hamer's and Donnelson's caves in Lawrence County, Clifty and some of the caves near Beck's Mill, Washington County, and nearly all those found elsewhere near the eastern limits of the St. Louis group.

Where the clay shales and argillaceous limestones are the surface rocks the country is very much broken by valleys that are quite different from the circular and oval depressions of the sinkhole region proper. Sinks are not wholly absent, but they are not characteristic. At many places the landscape is further modified, and the rock exposure obscured by a mantle of Loess clay that is continuous from East White River, north of Mitchell, over the oölitic and eastern argillaceous limestone area

to Salem, and on the east side of Harrison County. West of the Loess belt the lower Mitchell limestone is still the surface stone. Springs are not infrequent, and their waters combine to form small creeks that flow over the exposed edges of the strata until they reach the upper drainage level of the sinkhole area.

Small caves are common over the true cavernous limestone area and clearly show their connection with one or more sinkholes. The best known, and perhaps the largest, example of this class of caves in Orange County is found three miles west of Orleans, on the Peacher farm. Here the roof of the original cave has fallen at some period in the past and made two caves of what was once but one. The mouth of the west cave is large and opens into a wide room that terminates at the other end in a small but characteristic sinkhole. The outer roof of the east cave is low, and it can only be entered by crawling for quite a distance. Once inside, the explorer finds a capacious passage in which the sides below the middle converge to a narrow channel. The walls are covered with mud, and after a heavy rain both caves are filled with muddy water. Such so-called caves are a part of the underground drainage system of the country, and are peculiar in that they are near muddy passages, devoid of stalactites or other features that make caves so interesting to most persons. If it is kept in mind that sinkholes proper are circular basins, whose sides form a gradual slope from the rim to the bottom, they will be readily distinguished from another class where one or more of the sides is a precipitous wall of rock. The first are doubtless due to the slow chemical and mechanical forces that have tunneled the subterranean channel, the latter to the collapse of the roof of a vast cavernous opening whose arch had become weakened by a vertical fissure. At places there is evidence that the roof of the cave has fallen as much as ninety feet. This class of depressions impart to the landscape a peculiar, rugged, broken aspect, and impress the beholder with a feeling that old earth may at any moment slip from under his feet. Occasionally, at each end of the fallen mass, an opening may be found to the cave below. But usually the openings are small and do not appear to be anything more than woodchuck holes, until some winter morning the moist air of the cave, as it rushes out, is touched, as if by fairy fingers, and the shrubbery growing near hung with festoons of hoar frost. The angular depressions are found west of the small circular basins, and near the foot of the Kaskaskia group sandstone hills. Great blocks of Lost River chert cum-

ber the ground in marked contrast to the smaller fragments of the eastern margin of the typical sinkhole limits. It is possible that some of the circular depressions may have been exposed by the roof of a cave falling, but if such was the case there is no evidence of it left. The roof must have been composed of limestone as their rims are several feet below the geologic horizon of the Lost River chert. If limestone fragments of the roof were ever present they have disappeared; and the more probable theory seems to be that the depression is the result of erosive forces acting equally upon all the sides. The rocks exposed in place where the sinkholes are common in Lawrence, Orange, Washington and Harrison counties are always members of the upper or middle portion of the Mitchell limestone, and the angular chert masses and fragments scattered over the surface and mixed with the red residual clay come from the same strata or from the Lost River chert stratum.

The sinkhole area, as a rule, has no surface creeks and branches, and such as reach its limits from without soon find an opening and disappear wholly or in part, except Blue River and Buck Creek. Occasionally the creek or branch is replaced by a dry-bed channel. The dry-beds only come into use after heavy rains or when the subterranean passages are burdened beyond their capacity. Lost River through a part of its surface course is a typical dry bed. When it reaches the eastern edge of the sinkhole region it finds a number of underground channels that take in all the water of the perennial stream east of the Orleans and Paoli road. If the first openings are overtaxed, the overplus of water passes through a dry-bed channel farther west into other sinks, but after an excessive rainfall all the sinks fail, and water runs on the surface through the whole extent of the dry-bed system and again becomes a part of the perennial stream a short distance below the Orangeville "rise." Indian Creek for a part of the year runs underground, but, unlike Lost River, the greater part of its water passes over a surface channel and a dry bed is only exposed during the summer months. It sinks two miles southwest of Corydon and "rises" again five below on an air line, and twice that distance following the meanderings of the creek bed. There is ample evidence that Lost River, like Indian Creek, at some period in the past was wholly, or for the greater part of the year, a surface stream over its dry-bed channel.

Contrary to what might be expected, the subterranean channels do not greatly increase in capacity as they unite and pass under the Kaskaskia

Hills. This is shown four miles west of Orleans at what is called the "wet-weather rise" of the dry-bed. Here water flows out as it is flowing into the upper sinks, hence water may be flowing through two miles of the upper and lower course of the dry bed and not through the middle channel. As soon as the flood-water begins to recede at the "wet-weather rise" the direction of the flow changes, and, instead of running out, flows back into the opening from which it came. At times the whole underground system of channels is overtaxed and the water finds an outlet at many places, and occasionally through artificial openings, such as the well at Brookstown and another east of Orleans.

The underground channel of Lost River can be reached at three places through cavernous openings. At the first of these, near the first sinks, the superincumbent limestone is about forty feet thick; at the second opening the channel is not less than sixty feet below the Lost River chert; at Wesley Chapel Gulf it is thirty feet below the chert stratum, and the same at Orangeville. This indicates that the subterranean channel closely follows the dip of the strata to the west.

Comparatively speaking, sinkholes are rarely seen in the Upper Paoli limestone, and when they do occur are rough, angular openings in the limestone, of limited area. They are not an important feature in the surface drainage of the country, except in the valleys when located near the level of the Lost River chert.

The tendency of the subterranean channels to unite and diminish in capacity gives rise to a number of remarkable artesian springs that burst forth in great volume near the western limits of the Mitchell limestone exposure. The mouth of these springs seems to open into a vertical tunnel in the rock, and is always full of water that ordinarily flows gently away at one side. The deep blue of their water has given rise to the report that they are without bottom. After a heavy rain the volume of water discharged is very greatly increased and shows the effect of increased pressure. They are very unlike the wet-cave springs seen on the eastern limits of the St. Louis group limestone. The Orangeville and Shirley "rises" of Lost River and the Spring Mill head of Lick Creek are examples in Orange County. Those near Hardinsburg, Washington County, and the Harrison Spring and Blue Spouter, in Harrison County, are others of note.

Wyandotte and Marengo Caves belong to a class of caverns noted for their extent and great beauty. They do not seem to occupy a much higher

place in the St. Louis series of rocks than the sinkhole channels, but unlike them they are never inundated with floods of muddy water. Their exemption from overflows is due to the fact that the water-bearing channels terminate as artesian springs soon after they pass beyond the sinkhole plateau and under the Paoli limestone and foothills of the Kaskaskia sandstone. The artesian springs are found east of the Crawford County caves, and, if this was not the case, the deep valley of Blue River as it runs south on the eastern boundary of the county, would terminate the westward trend of the underground drainage system of Harrison County. The entrance to the Wyandotte cave is 150 feet above Blue River; and none of the cave entrances of this class are below or on a level with the creeks of the surrounding country, as they are where sinkholes are common. Where the Mitchell limestone is well protected by the overlying Paoli limestone and Kaskaskia strata, caves of any kind are rare, but when they do occur they are very interesting and should be thoroughly explored.

In Missouri, it is said that when the coal measures strata rest immediately on the St. Louis limestone, deep borings pass through cavernous openings,* which is explained by the theory that the St. Louis was for a time dry land and more or less tunneled before the coal strata were deposited.† There is very little data to show that the Indiana St. Louis is cavernous for any great distance beyond the surface sinks. As the sinks are only common where the Paoli limestone has been removed it is reasonable to suppose they do not occur under other conditions, and this view is confirmed by what has before been stated. Two deep wells have been drilled at Paoli and no caverns noted. At Orleans, in one out of three wells, the drill passed through a cave at one hundred feet below the surface; but the latter town is located on the cavernous limestone and the former is not.

In comparing the caves of Indiana with those of Kentucky it is well to remember that in the immediate vicinity of Mammoth Cave, according to competent authority, the Kaskaskia group strata are wanting, and the capping stone of the St. Louis is one of the sandstone members of the lower coal measures. Some of the Kentucky caves are said to reach up to the sandstone, but if the same is true of the Indiana caves the fact has not been noted, nor is it probable that such will be found to be the case.

* Keyes' Mo. Geol. Sur. XI, p. 252.

† Keyes' Mo. Geol. Sur. IV, p. 73.

The chemic composition gives a hint as to the origin of the St. Louis caves, and bears out the conclusions here presented. Prof. John R. Proctor says* that in the vicinity of Mammoth Cave the subcarboniferous limestone is "a massive, remarkably homogeneous rock with no intervening strata of shale or sandstone, conditions most favorable for the formation of caverns." In the main his statement is true of the equivalent strata in Indiana, but does not take into consideration certain beds of limestone that weather to a calcareous shale or the variable chemical structure of the Indiana stone, both important elements in studying the relations of the strata to the caves they bear. Probably more to the point is the statement of Prof. W. H. Wheeler,† who, in writing of the topography of St. Louis County, Missouri, says: "The limestones of the St. Louis area are very hard, tough, and resist mechanical disintegration, but on account of the prevalent *purity*, they are very susceptible to chemical dissolution." "If the upper portion of the limestone is impure, and especially if high in magnesia, it is much more resistent to chemical dissolution, and the sinkhole method of drainage is frequently absent. In this case the drainage is by surface channels, which are abrupt and irregular and vary sharply from gentle to heavy slopes." But, while it is conceded that homogeneity and purity largely determine whether the dissolution is chemical or mechanical, they do not appear to fulfill all the required conditions. The Bedford oölitic and Paoli limestones, by chemical analyses, are shown to be from 95 to 98 per cent. calcium carbonate, and the Mitchell limestone less rich in lime by 10 per cent., yet the first two formations have but few caves, while the last is undermined with cavernous openings. That the surface exposure of the Mitchell limestone contributes greatly to its disintegration has already been mentioned, but this does not explain its inherent susceptibility to chemical dissolution. If the number of analyses of the St. Louis limestones above the Bedford oölitic are not near so many as one would wish, those which are available seem to be suggestive. Dr. G. M. Levette, under direction of Prof. E. T. Cox, made a number of analyses of hydraulic cement rock from the lower Mitchell limestone strata of Harrison County, and as equivalent beds of cement rock are found at Becks Mill, Clifty, and many other places, one of them is here given.*

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*The Century Magazine, March, 1898, p. 643.

† Keyes' Mo. Geol. Sur. XI, p. 249.

* Geol. Sur. Ind., 1878, p. 75.

No. 1.—Cedar Grove cement rock.

Water expelled at 212° F	1.00
Insoluble silicates	27.70
Soluble silica	.10
Ferric oxide and alumina	4.00
Lime	35.00
Magnesia	trace
Carbonic acid	27.50
Sulphuric acid	trace
Organic matter, undetermined and loss	4.70
	100.00

The following analyses† were made by Mr. G. A. Kerr for this paper:

No. II.—Bluish-gray, hard limestone with chert inclusions; two miles east of Orleans on the Livonia road. Below the Lost River chert. Specific gravity, 2.68.

Insoluble silica	10.670
Iron	0.304
Magnesia	.461
Alumina	3.210
Calcium carbonate	84.920
Undetermined	.435
	100.000

No. III.—Gray, weathered, friable limestone, from the surface of a bluish-gray, lithographic limestone, one mile west of Union Church and three miles southwest of Orleans. Below the Lost River chert. Specific gravity, 2.44.

Silica, insoluble	5.580
Iron	0.257
Magnesia	0.284
Alumina	3.010
Calcium carbonate	89.904
Undetermined	.965
	100.000

† Thanks are due Mr. G. A. Kerr, chemist to the W. W. Mooney & Son's tannery company, Columbus, Indiana, for kindly making analyses Nos. 2, 3 and 4 at my request.

No. IV.—Drab, fine-grained lithographic limestone. Wesley Chapel Gulf, three miles east of Orangeville. Fifty feet above the Lost River chert near the middle of the Paoli limestone.

Silica, insoluble	1.520
Iron, ferric oxide	.278
Magnesia	.712
Alumina	1.555
Calcium carbonate	95.001
Water expelled at 110° C	.630
Undetermined and loss	.304
	100.000

One of the first things to be noted in the Mitchell limestone analyses is the persistent presence of a much larger per cent. of silica than is common to an otherwise pure limestone; and it is at least singular that the quantity of silica should be reduced one-half in the weathered specimen from the same horizon. To test whether the less percentage of silica in specimen No. 3 might not be due to a difference in the chemical composition of the unweathered stone from which it was taken, the soft, gray, broken-down surface of No. 2 was tested, and found to contain but 4.82 per cent. of silica as against the 10.67 per cent. of the unweathered mass. The silica from all the analyses was disengaged as an impalpable powder, and it is singular that the insoluble silica should be the first one of the salts to disappear in the process of dissolution. Another fact of note is the constant presence of alumina and a small quantity of magnesia. The low percentage of magnesia doubtless explains why the Mitchell limestones are so readily disintegrated by carbon dioxide in solution.

SUMMARY.

The caves of the St. Louis group in Indiana may be divided into three classes: The wet caves of the lower and more impure Mitchell limestone; the subterranean channels, caves and sinkholes of the middle and upper Mitchell limestone, and those of the upper Mitchell and Paoli limestone. And as to origin: Those in which mechanical forces were dominant; those in which the mechanical and chemical action was nearly equal, and those in which chemical dissolution was the principal factor.

Jug Rock. By Chas. R. Dryer.

Jug Rock is a sandstone pillar forty-five feet high, capped with conglomerate, standing alone upon the slope of a ridge or bluff of White River near Shoals, Ind. It is almost exactly similar in form and material to the monuments in Monument Park, Col. (Photographs and specimens

Jug Rock.

from both were shown). In Monument Park there are a hundred similar forms; in Indiana but one. The most remarkable thing about Jug Rock is its uniqueness. How conditions could have been adequate to produce one such pillar and did not produce more than one is a puzzle. At other points along White River, as at "the Pinnacle" and "Pike's Rest," some tendency to the formation of similar phenomena is shown.

Pike's Rest.

The Pinnacle.

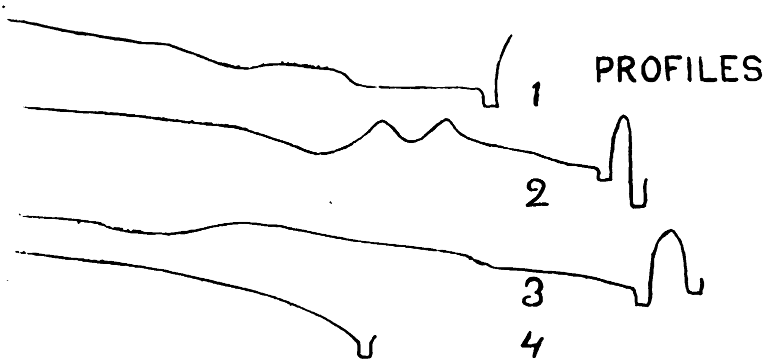
THE ST. JOSEPH AND THE KANKAKEE AT SOUTH BEND. BY CHAS. R. DRYER.

THE MEANDERS OF THE MUSCATATUCK AT VERNON, INDIANA. BY CHAS. R. DRYER.

At Vernon, Ind., the Muscatatuck River presents a remarkable group of meanders. In a course of six miles it forms four loops, enclosing four tongues of land which are connected with the mainland by very narrow necks. The distance in a straight line from the upper end of the first loop to the lower end of the fourth is less than a mile and a half, and the perpendicular fall about fifty feet. The general level of the upland on both sides of the valley is about 750 feet; the level of the river varies from 630 to 580 feet. Three of the enclosed tongues slope quite regularly from neck to point. Tongue No. 1 is crossed at about its middle by a twenty-foot terrace, below which the surface is at a uniform level of 655 feet, corresponding with the top of the hard Niagara limestone. The tip of the point is alluvial deposit. Tongue No. 2 is occupied by the town of Vernon, and differs from the rest in that the surface slopes from a high and narrow neck rapidly to the 660-foot level, then rises in a double-peaked hill to 715 feet, then slopes gradually to a broad point near the 655-foot level. Tongue No. 3 has a neck only 300 feet wide at the bottom and about ninety feet high. The body of it is about one-fourth of a mile wide and one mile long with a very uniform slope. There is a slight terrace at the 670-foot level, a decided flattening at 650 feet and a rather broad alluvial tip. Tongue No. 4 is the smallest of the group and has the steepest and most symmetrical slope.

The channel of the Muscatatuck is 200 to 300 feet wide and cut down from twenty to fifty feet into the Niagara limestone, which forms bluffs of corresponding height on both sides of the stream. There is practically no flood plain.

The origin of these meanders is a difficult problem. They are very unlike ordinary flood-plain meanders, in which the tongues of land are flat and but little above stream level. They differ also from upland meanders, in which not only the channel but the whole valley winds, the tongues maintaining a uniformly high level and terminating in a bold headland. These are shown in great perfection by the Osage River of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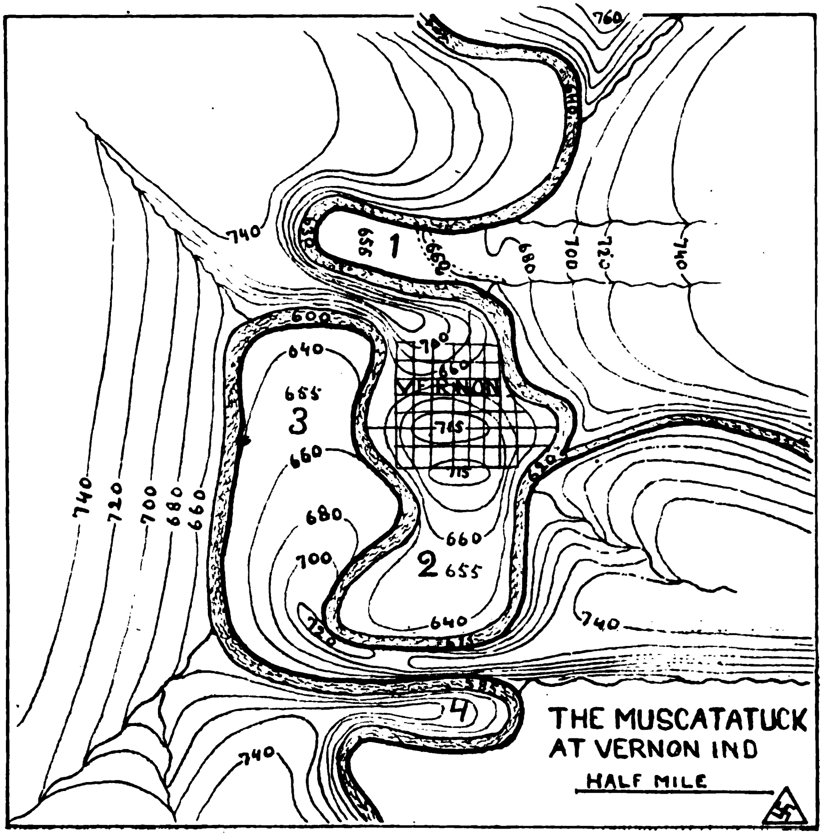

THE MUSCATATUCK
AT VERNON IND
HALF MILE
VERNON
1
2
3
4
740
720
700
680
660
655
640
600

Missouri. Meanders with sloping tongues, form a class by themselves. and have been most fully discussed by C. F. Marbut of the Missouri Geological Survey.* He publishes maps of the meanders of the Grand and Flat Rivers, but none of them are quite equal to the Vernon tangle of the Muscatatuck.

Two hypotheses have been suggested to account for meanders which are not due to flood-plain conditions. Prof. W. M. Davis has suggested† that they may be superimposed or inherited from a former flood-plain condition. In some previous period the stream has reached base level and developed flood-plain meanders. The basin has been subsequently elevated and the stream in its new cycle has cut its old meanders straight down into the plateau. This may serve to explain meanders in which the tongues are headlands, but evidently will not apply to those of the Muscatatuck, which are not cut straight down.

Winslow‡ thinks such meanders are due to a normal growth and development from an originally crooked consequent course. The germ of the present remarkable loops existed in the slightly irregular surface of the country over which the stream first began to flow. As it corraded its channel more deeply it cut away the convex sides of its bends. It thus became more and more crooked, and by a combination of vertical and lateral corrasion, it slid or sidled down the long slopes of the tongues.

The meanders of the Muscatatuck seem to be better accounted for by development than by inheritance; but the process has been somewhat modified by peculiar conditions. During the cutting of the first seventy or eighty feet, lateral corrasion was more rapid than vertical, and the long gentle slopes of the tongues were formed. At about the 675-foot level vertical corrasion, for some reason, became more rapid and a twenty-foot terrace was formed. At the 655-foot level the stream came down upon the hard and massive Niagara beds, or the corniferous limestone which thinly overlies them. Vertical corrasion seems to have ceased for a long period, during which the stream slid laterally and planed off the broad, flat points of Tongues No. 1 and No. 3. Then came a decided change, probably an elevation of the land and an increase of the slope, which has enabled the stream to cut its channel almost vertically downward into

* Missouri Geological Survey, Vol. X, p. 98.

† Science, Vol. 22, p. 276.

‡ Science, Vol. 23, p. 31.

the Niagara limestone to a depth of from twenty to fifty feet. The small alluvial deposits at the tips of the present tongues show that lateral cutting has not entirely ceased. The hill on Tongue No. 2 may possibly be due to a cut-off formed at about the 660-foot level. The possible course of the stream at about the 670-foot level need not then have been very crooked. Most of its tortuousness has been developed since it struck the Niagara limestone. The nomenclature of the subject is somewhat unsettled. The land enclosed by a meander is called a neck, point or tongue. I propose that the word *tongue* alone be used to designate that feature; that the name *neck* be reserved for the often narrow portion where the tongue joins the mainland, and the name *point* be used only for the tip or extremity of the tongue. In cases where the point is high, as on the Osage River, the term *headland* is natural and descriptive of the whole tongue. For those tongues which slope regularly from an elevated mainland or neck to a low point I propose the analogous term *tailland.*

Taillands are probably not peculiar to the Muscatatuck. I have observed good specimens on Sand Creek at Brewersville and on Laughery Creek at Versailles. The subject is now broached, as far as I am aware, for the first time in Indiana and would probably repay further investigation.

Old Vernon—A Geographical Blunder. By Chas. R. Dryer.

The town of Vernon, the county seat of Jennings County, Indiana, was founded in 1816 at the forks of the Muscatatuck River, which was the head of flat-boat navigation. It is located upon a high, rocky tongue of land, surrounded by the gorge of the river, except at one point, where a neck 130 feet high and just wide enough at the top for a roadway connects it with the mainland. The area enclosed is about one-fourth of a square mile, which is bounded, except at a few points, by perpendicular bluffs from 40 to 90 feet high. It rises at the center in a double-peaked hill 100 feet above the river. As a site for a medieval castle with a cluster of cabins around it, designed primarily for defense, it is unrivaled. It is a Hoosier Ehrenbreitstein. As a site for a modern commercial town it is a failure. In 1850 the Ohio & Mississippi Railroad passed about two miles north of it, and the business center was soon transferred to its station, North Vernon. Other railroads have come to North Vernon since,

but on account of engineering difficulties, only one touches Old Vernon, and, by a long fill and double bridge 80 feet high, crosses the river at the forks. The population of North Vernon is 3,000; of Old Vernon, 650. The courthouse and jail seem to be the only reason for its existence, but its quaint and picturesque beauty give it a charm which no smart business town can possess.

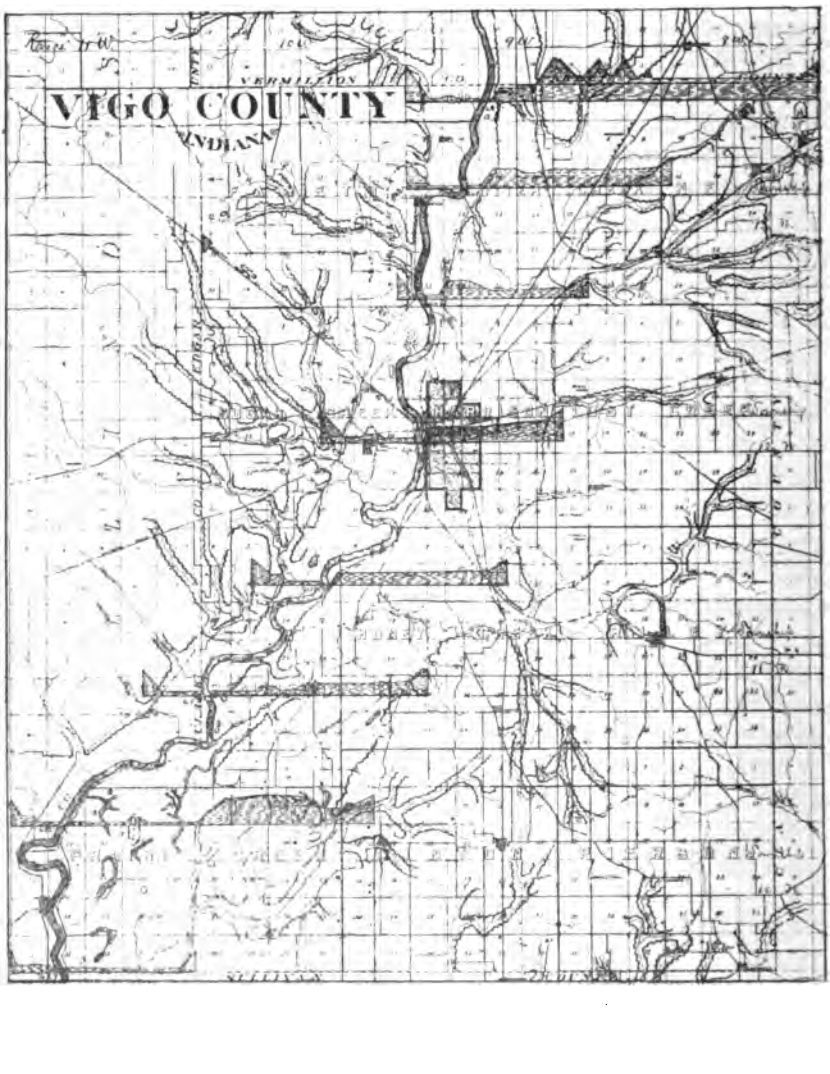
Terraces of the Lower Wabash. By J. T. Scovell.

The valley of the Wabash, while much like many others, has some peculiarities. It was dug out through the sand and gravel that partially filled an ancient drainage channel. The old channel in Vigo County is from four to six miles wide, and at Terre Haute the bed of the present river is 100 feet above the rock bed of the old river. A long, narrow island whose southern extremity extends a mile or so into Vigo County divided the old river into two channels. The main channel, on the west of the island, now occupied by the Wabash, is about two miles wide. Near the county line it received a tributary channel about one-half mile wide, now occupied by Brouillet's Creek. The eastern channel is about a half mile wide, and is occupied by the lower course of Raccoon Creek. Near the county line this channel received the tributary channel of Old Raccoon Creek, about a half mile wide. Thus the old valley in Vigo County was formed by the union of four broad channels. The flood plains and the terraces of the present river rise to different elevations above low water, and vary considerably in width. Some of these variations are shown by cross sections of the valley made on different lines along its course.

The first section is along the north line of the county. The datum, low water in the river, is about 452 feet above tide. The flood plains on the west rise from 12 to 20 feet, a flood of 16 to 18 feet covering much the greater part with water. The second bottom rises about 30 feet above low water, and the bottoms of Brouillet's Creek are continuous with those of the river. The bluff on the west rises abruptly from Brouillet's Creek to an elevation of about 600 feet. On the east a rise of about 50 feet reaches the edge of a heavy gravel terrace, which rises gently toward the east, reaching an elevation of 520 feet at the foot of the island bluff one mile from the river. Thence across the island, whose higher points are about

600 feet above tide, to the terrace on the east at an elevation of 537 feet, about 85 feet above low water in the river. The next section, about three miles south, shows low bottoms on each side of the river, but no second bottoms. The big terrace near the river is perhaps a little higher than on the county line, but two broad valleys appear farther east which greatly reduce its volume. The third section, between three and four miles farther south, shows low bottoms, less than a mile wide, mainly east of the river. The terrace rises from the flood plain to an elevation of from 80 to 90 feet above low water, but soon descends to an elevation of only 45 to 50 feet above datum, in the valley of Otter Creek. Erosion by the creek may account for the great reduction in the volume of the terrace, as shown by this section. The section at Terre Haute, 3½ miles farther south, shows about one mile of low bottoms on the west, then a second bottom rising about 30 feet above low water, then low bottoms to the bluff. On the east a rise of 50 feet reaches the edge of the terrace, which rises gradually but irregularly to an elevation of about 70 feet at the bluff three miles from the river. Two low ridges and two shallow valleys occur on this section, but in general the surface of the terrace is more uniform than farther north. The next section, about four miles farther south, shows about one mile of flood plain on the west and a narrow terrace rising about 45 feet above low water in the river. On the east the terrace, nearly level, is about four miles wide, having an elevation of about 45 feet above low water. The ridges of the Terre Haute section show faintly, but the surface in general is uniform. The section three miles farther south, through the village of Prairieton, shows a little more than two miles of flood plain about equally divided by the river. The terrace about four miles wide has an average elevation of about 45 feet above low water. Honey Creek has cut a broad valley across the terrace, and a low ridge appears farther east. The next section, 3½ miles farther south, shows one mile of flood plain west of the river, and a narrow terrace. On the east the low bottoms are 3½ miles wide. A little island of gravel rising about 40 feet above low water, and a narrow sand ridge, are the sole representatives of the great terrace farther north. This section continued eastward shows that Johnson's Hill rises about 100 feet above low water in the river and that the valley of Prairie Creek, about one mile wide, has about the same elevation as the Prairieton terrace. It seems probable that Johnson's Hill was an island in the old river, and that the valley of Prairie Creek was the eastern channel of the ancient

stream. The sand and gravel of Prairie Creek valley, probably representing the terrace, as shown in the Prairieton section. The section on the south county line shows three miles of flood plain east of the river. This plain is low along Prairie Creek and is crossed by a low, rocky ridge near the bluffs. West of the river the terrace is about two miles wide, with an average elevation of about 35 feet above low water in the river.

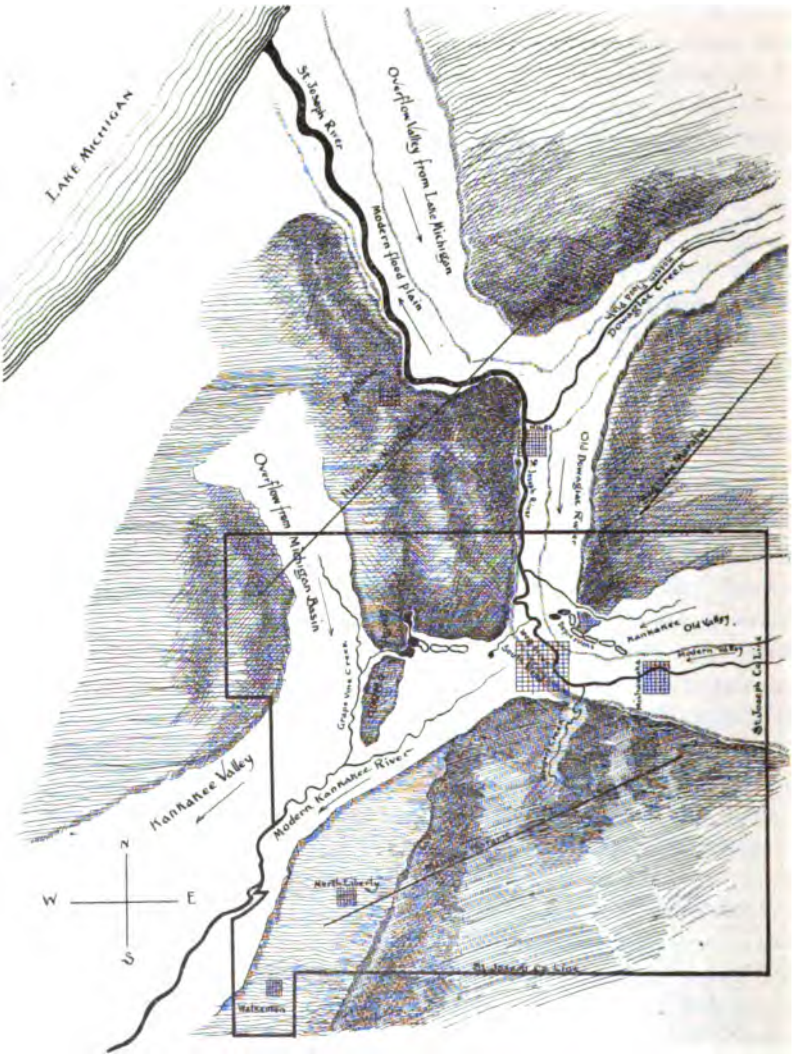


A low, broad ridge is shown upon the terrace, but in general its surface is quite uniform. This terrace descends gently toward the south so that at York, six miles south, it has an elevation of scant 30 feet above low water, while at Hutsonville, five miles below York, it has an elevation of only about 25 feet, just about on a level with the high floods, and only about 80 rods wide. Just north of Hutsonville there is a great hill of sand and gravel that rises about 45 feet above low water, but the greater part of the terrace is low. Thus the gravel terrace, so massive, so prominent a feature in Vigo County, almost disappears within 40 miles. It seems probable that the old valley was once filled with sand and gravel, at least to the elevation of the higher points of the present time. The present features of the valley are apparently due to extensive erosion. Meander lines run in 1816 show that the present river has not eroded its gravel banks to any appreciable extent during the past 80 years. The work of erosion signifies much stronger currents than prevail in the present river, even when in flood.

THE KANKAKEE VALLEY. BY H. T. MONTGOMERY, M. D.

One of the great waterways during the ice period seems to have been entirely overlooked by our local and State geologists. I refer to the great Kankakee Valley, whose stream had its origin at the foot of the Saginaw glacier, and received tributary streams from the Maumee and Michigan glaciers, and became in time the outlet for the waters flowing south from Lake Huron through Saginaw Bay before they secured an outlet through the Niagara River. This great valley served as a waterway for the waters during the withdrawal of the first ice sheet, from the fact that its channel was silted up like all other great stream valleys during the Champlain epoch or age of depression, and was never re-excavated to any extent, and remains to-day a filled valley. It probably conveyed the waters during the advance of the last ice sheet, but soon after the sheet began to withdraw the waters found an outlet into Lake Michigan, leaving the Kankakee Valley at the point where South Bend now lies, through the bed of its largest tributary, which will be described later on. The Kankakee Valley extends from a point in Illinois where the present Kankakee River and the Desplaines unite, taking a northeasterly course through Illinois, Indiana and Michigan, to the watershed between the streams

flowing into Saginaw Bay and the head-waters of the St. Joseph River, which flows southwest through the Kankakee channel to South Bend, where it abruptly turns north and reaches Lake Michigan at St. Joseph.



St. Joseph County.—Showing Ancient and Modern Drainage.

This valley was the great outlet to Lake Huron, as the Wabash Valley was the outlet to Lake Erie during glacial times. This great valley, with its flood plain, varies from three miles at its narrowest point, which is one mile below South Bend, to about twenty at its broadest part, which is between Porter and Lake on the north and Newton and Jasper counties on the south. The south bank of the valley from about six miles below South Bend to near its source is from fifty to one hundred feet high, while the north bank from South Bend to its source is generally low and shelving. From South Bend to the Illinois line, or from the point where the valley emerges from between the Maumee and Michigan moraines to its confluence with the Desplaines, the banks are low, generally not exceeding fifteen or twenty feet in height. On the south side of the old channel will be found quite an extensive sandy flood plain, extending from the border of the Maumee moraine southwestward, covering almost the entire surface of Starke County, the northern part of Pulaski, Jasper and Newton counties. On the north the main channel largely borders the Michigan moraine.

The great width of the stream from South Bend to the eastern part of Illinois was owing to three causes—first, the surface of the country through which this part of the stream flowed was destitute of rugged features, being a comparatively level, smooth surface; second, the stream crossed the arched condition of the bed rock which extends in a northwesterly course across Indiana into Illinois; this rocky ridge probably produced well-marked rapids, similar to those of the Ohio River near Louisville, and also had a marked tendency to dam the waters and cause them to overflow a wide territory above, giving to this region the general appearances of a great lake having occupied its territory; third, at South Bend, a tributary one-third its size was added to its volume; also the overflow from the Michigan basin through the Grapevine Valley.

The principal tributaries of the great Kankakee were the Elkhart and Yellow rivers, draining from the Maumee glacier, and probably the Tippecanoe River at a point where it enters the southeast corner of Starke County; this I have not carefully investigated, but which I think will probably be found to be a fact, also what I am pleased to call the great Dowagiac River, now represented by the Dowagiac Creek, which heads south of Kalamazoo, Mich., but the waters of whose ancient stream probably accumulated far north of that point, gathering all the glacial waters from the eastern slope of the eastern lateral moraine of the Michigan

glacial lobe, forming a mighty glacial river, flowing south to a point three miles north of Niles, Mich., where it received a large tributary which had opened a way through the lateral Michigan moraine, and was discharging its waters from the Michigan basin, which had not yet found an opening to the south, between the Michigan ice lobe and its moraine. The Dowagiac River, after receiving the overflow waters from the Michigan basin, continued south and emptied its waters into the Kankakee at the present site of the city of South Bend.

The old channel where it emptied into the Kankakee is three miles wide, with well-defined banks rising from fifty to seventy-five feet above the bed of the valley, the valley having been cut to bed rock and silted up about 120 feet, leaving the above-mentioned banks yet remaining.

These great streams existed for long periods of time. The Kankakee and the Dowagiac conveying the glacial waters during the advance of the ice sheet, also during the period that it stood at its most advanced point, and during its withdrawal, until the Michigan ice lobe had sufficiently receded to allow the waters along its eastern border to escape through the Desplaines opening. This promoted a rapid lowering of the waters between the ice lobe and its terminal lateral moraine, and terminated the flow of waters from the Michigan basin into the Dowagiac River, leaving a broad water-worn plain leading from the Dowagiac River back northwestward to the Michigan basin.

Here commenced a system of river robbing. The Dowagiac River doubled upon itself at an angle of 45 degrees, followed the abandoned channel of its former tributary and discharged its waters into Lake Michigan, leaving in turn a well-worn channel from three to four miles wide and thirteen miles long, leading to the great Trunk Stream or Kankakee. The distance from the point where the Dowagiac emptied its waters into the Kankakee to St. Joseph, Mich., is thirty-eight miles, with a fall of 141 feet; from the same point to Momence, Ill., the distance is 92 miles. with a fall of 93 feet. It can be readily understood that, with the first annual flood, a part of the waters of the Kankakee would follow the abandoned Dowagiac channel, mingling with the Dowagiac, and onward into Lake Michigan at St. Joseph. The fall over the new route being three and a half times greater than that over the old route, the new channel rapidly cut through the old river deposit, finally claiming all of the waters of the once mighty Kankakee, leaving its valley from South Bend to the Desplaines a geological monument to tell of its eternal past.

The physical force which most likely turned the current of the Kankakee into the channel of the Dowagiac was an ice gorge, forming seven miles below South Bend, where a jutting point from the Michigan moraine extends out into the valley proper, two miles and a half, in an almost transverse direction, and known as Crum's Point. Just below this point we find an ancient flood plain two miles wide, which was supplied with overflow water from the Michigan basin, and which entirely subsided when the Michigan waters receded from the rim of its basin. This valley is drained by a small meandering stream, known as Grapevine Creek, the rudiment of a mighty glacial stream. Strong and well-pronounced evidences of an ice gorge or dam having formed at Crum's Point, and extending up the river to the mouth of the Dowagiac, are yet plainly visible, from the scouring, leveling and erosion of the morainic hills on the south, and a chain of lakes, and lake beds on the north, which are connected by a gorge through the point with the glacial stream mentioned above. And also at the head of the ice dam which passed well up above the mouth of the Dowagiac, where the waters pouring around it into the Dowagiac Valley excavated an interrupted channel, or chain of depression. These depressions are linear, extending from northwest to southeast, being from one-fourth to three-fourths of a mile long, twenty to forty feet deep, and from two hundred to six hundred yards wide, with sharp and well-defined banks. They all show evidences of having been filled with water for a long period of time. All have become dry except the lower two, which contain from twenty to thirty feet of water at present. This channel or chain of depressions extends from one mile north of South Bend southeasterly to within one mile of Mishawaka, a distance of four miles and a half, as shown on the accompanying diagram. When the ice dam gave way, the waters abandoned their circuitous routes and resumed their old channels, a part of them at this time taking the route down the Kankakee, and a part of them up the Dowagiac Valley, the fall the latter way being three and a half times greater than the former, a channel was soon eroded sufficiently to carry the entire volume of water. A bluff twelve to fourteen feet high, which commenced in the form of a sandbar, the sediment for which was supplied by what is known as Wenger's Creek, extending in a diagonal direction across the Kankakee bed, and parallel to the new current, until it reached the opposite bank, when the Kankakee Valley was sealed forever.

The Kankakee River, from its source to its mouth, took a southwesterly course. When the waters left the old channel they took an almost due northerly course, forming a great bend in the river, with its sharp convexity to the south, which gave our city its name—South Bend.

The two rivers since changing their course have eroded their valleys from fifty to seventy-five feet into the old river deposits, and have not yet attained their base level. The Kankakee Valley at South Bend, where it escapes from between the Maumee and the Michigan moraines, is narrowed down to three miles, with high rugged banks and no flood plain. Five miles east, and up the valley from South Bend, it attains a width of six miles, which width it holds with slight variation until it reaches the rim of the Saginaw basin. This end of the valley is thoroughly drained by the channel of the present St. Joseph River, which has eroded through the old river drift to the extent of from forty to fifty feet. There are a few peat bogs and marshes lying back from the river, where the valley is broad, and the modern channel well to one side. Otherwise the old valley above South Bend is one vast level sand plain. Below South Bend, where the old valley remains silted up, and there is no modern channel for drainage purposes, the spring waters escaping from beneath the Michigan moraine, and from the foot of the Maumee, also bubbling up from the bed of the old stream itself, as I am informed by Mr. William Whitten, in charge of rock excavations at Momence, has been productive of a vast growth of peat or muck over the entire valley proper, from South Bend to Momence. Beneath this peat bed, which ranges from six to ten feet in depth, is found fine sand and river gravel, as shown by excavations made in the construction of a large ditch made with the view of straightening the river. This ditch commences at South Bend, is twenty feet wide, ten feet deep, and twenty miles long, which gives us a comprehensive idea of the materials underlying the bog. If the stream had not changed its course at South Bend and continued down its original valley, eroding a channel or partially cleaning the old silted valley to a depth of from fifty to sixty feet, as the waters have done through their new course, rendering to the Kankakee Valley thereby proper drainage, there would never have been known a "Kankakee Marsh," but all that portion of Indiana would have been a vast sandy plain, covered with oak or barrens timber, and in general appearances the same as that part of the valley above South Bend,

Notes on the Eastern Escarpment of the Knobstone Formation in Indiana. By Lee F. Bennett.

One of the most noticeable topographical features of Indiana is the eastern escarpment of the Knobstone formation. It can easily be traced from New Albany in a north-northwesterly direction for more than one hundred miles.

The Knobstone formation comprises the lower strata of the Sub-carboniferous series in Indiana. It is made up of clay shales, sandy shales and sandstones. The escarpment is due to a great thickness of the soft and easily eroded strata capped by more resisting strata of sandstone and overlying limestone. It generally faces east, and in the extreme southern part of the State it presents a bold precipitous face. Here the name "Knobs" is given to the range of hills formed by the escarpment; farther north this eastern portion of the formation is known as "the hills."

Beginning directly west of New Albany, in Section 3, township 3 south, range 6 east, the escarpment runs north ten miles. It varies from 190 feet to 385 feet above the country to the east which is low and flat and slopes gently towards the Ohio River. There are no foot-hills in this region, but in various places streams have cut through the escarpment forming narrow ravines with almost precipitous sides. With the exception of about two miles where limestone a few feet in thickness is found, sandstone is the capping stratum. In a typical section made six miles north of New Albany the sandstone was found to be 90 feet in thickness and the shale nearly 300 feet.

The drainage is toward the east into Silver Creek or southeast into the Ohio River. A few of the streams head two or three miles west of the escarpment and reach the level country through the narrow ravines before mentioned. The escarpment turns to the west in section 14, township 1 south and 6 east, Clark County, forming the southern boundary of the valley of Muddy Fork Creek as far as the town of Borden.

The knobs in this region vary from 150 to 250 feet in height and are capped by sandstone. Near Borden the knobs are for the most part made up of shales containing large quantities of iron nodules.

On the north side of the valley of Muddy Fork Creek the escarpment extends eastward to section 6, 1 south and 6 east, whence it runs in a north-northeasterly direction twelve miles to section 19, 2 north, 5 east, which

is the most easterly extension of the Knobstone escarpment. Foothills are found in the northern part of township 1 north; they extend one mile to the east of the main escarpment, are low and for the most part uncultivated. The Sub-carboniferous limestone which overlies the Knobstone has receded many miles to the westward, thus leaving the sandstones and shales to make up the hills of this region. In section 24, 2 north and 8 east, on the line between Clark and Scott counties, probably the highest part of the escarpment is found; it is 400 feet above the general level of the country to the east. (The hills of section 24 and 25 are cut off from the main line by a gap cut by streams tributary to the Muscatatuck on the north and the Ohio on the south.)

The line of hills now turns westward, then northwestward twelve miles, passing into Washington County, and again turns west. In township 2 north, 6 east, there are several small valleys cut by streams tributary to the Muscatatuck. The foothills are long, extending two or three miles northeast parallel to the principal creek beds. In township 3 north, the overlying limestones extend to the eastern face of the Knob escarpment.

In section 30, township 4 north, 8 east, the hills turn to the west, running parallel to the Muscatatuck and White rivers. In places the hills "bluff up" against the river and in others the "bottom land" is a half mile or more in width. In the eastern part of township 4 north and 4 east, the line of hills makes a great bend towards the south; another deflection is made to the southeast in the middle of township 4 north and 3 east. In section 26, township 4 north and 2 east, in northwestern Washington County, limestone is found capping the escarpment 125 feet above the river bed and is found as the capping stratum for several miles farther down the river; the hills forming the border of the valley vary from 125 to 300 feet in height.

From Ft. Ritner, on the north side of White River, the hills extend northeast for six miles to near the town of Medora, then nearly north for ten miles to Freetown in the northwestern part of Jackson County. In the first seven miles of this portion there are no foothills, the White River bottoms extending to the face of the escarpment; farther north there are foothills and in many places there is a gradual rise from the eastern lowlands to the hills to the westward. In a few places only are the hills as high as they are to the south. One hill was measured which was 370 feet in height, but this was an exception. In the vicinity of Freetown, in town-

ship 6 north and 3 east, the highest hills along the eastern face are but little over 100 feet. They form the watershed for this section of the country.

East and south of Brownstown, in east-central Jackson County, are the "Brownstown Hills." They are outliers of the hills to the south and west. They are separated from the main line of hills to the south by the Muscatatuck River and two and one-half miles of bottom land; from those on the west, by the White River and four miles of bottom land. They are a very prominent feature in the topography of this region; their greatest extent is six miles from north to south and five miles from east to west. They are made up of muddy sandstones underlaid by clay shales and contain in many places considerable quantities of iron nodules. The hills in many places are nearly 400 feet above the valley; on the east the slope is rather abrupt, with few foothills, but on the west the slope is gradual to the White River bottoms. The hills are nearly cut through in three places by creeks tributary to the White River.

From Freetown the hills extend to the northeast six miles near the Bartholomew and Jackson county line, thence nearly north across the western part of Bartholomew County. Near the above-named county line one spur of the hills runs nearly east for three miles, then in a northerly direction, forming the foothills in Bartholomew County. The Knobstone escarpment is generally not well marked in this county. In a few places the slope is gradual; in other places the foothills are five or six miles wide and the escarpment is well marked. Without doubt two or three miles of these lower hills are partially formed of drift, as was shown by well sections obtained in this region; a few places along the west bank of Driftwood River there are bluffs 100 feet high.

The main escarpment varies from 100 to 275 feet above the immediate country to the east. The creek valleys in the lower hills are sometimes more than one-half mile in width. In the northern part of the county in township 10 north and 4 east, there is no distinct escarpment; the country gradually becomes more rolling from the east to the west and passes into the hills of northern Brown and southern Johnson counties.

Beginning with Johnson County the real eastern escarpment is covered with glacial material. In township 11 north and 5 east, extending to Sugar Creek west of Edinburg, the country is gently rolling with an occasional bluff on the west side of the creek; in township 11 north, 4 east, the hills are steeper and more numerous. In township 11 north 4

east, and 12 north 3 east, west and southwest of Franklin, the watershed between the east and west forks of White River is a ridge covered with a glacial material; it is almost level and from one to two miles in width.

The glacial covering can be easily traced along the southern part of this ridge. Here the wells are shallow and water is found in shale; farther north the water is found in gravel and sand, and in this region there is a number of large springs. Well sections also show the character of the original surface; of two wells within seventy-five yards of each other, one was 14 feet deep and the bottom was in blue shale; the other 41 feet deep and the bottom was in a "brush heap" (glacial debris).

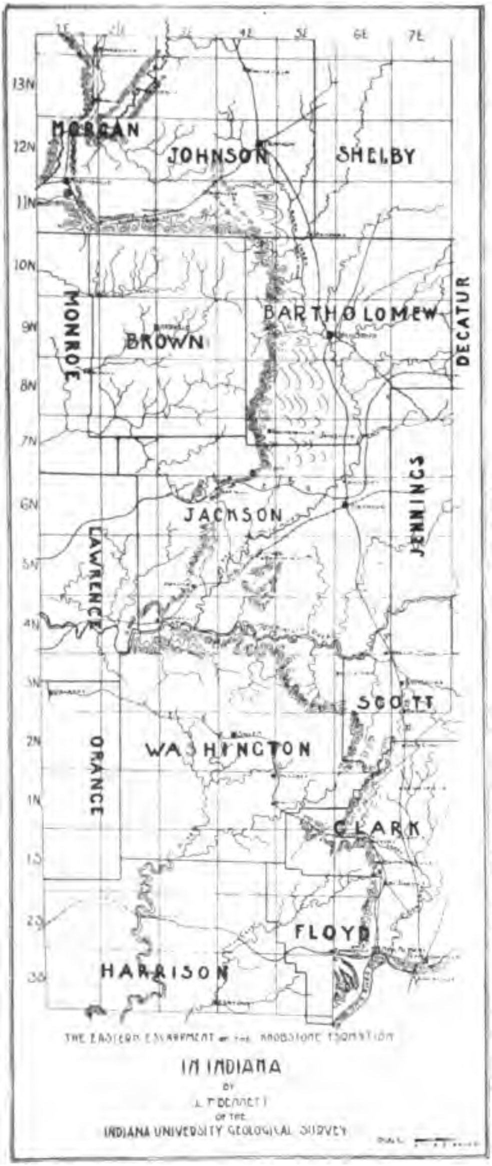
West of this ridge to White River, and especially along the creek beds, the country is very rough and shows the characteristic Knobstone topography. A continuation of the hills of northwest Bartholomew County are found in southern Johnson and Morgan counties; the hills are from 75 to 125 feet above the bed of Indian Creek which they follow to its mouth, three miles southwest of Martinsville.

On either side of White River north of Martinsville to near the Morgan and Johnson county lines, typical Knobstone bluffs are found. Directly west of Martinsville the bluff is 190 feet high. The bluffs on the west side follow close to the river for about five miles; they then turn to the north, forming the west side of the valley of White Lick Creek. They gradually become lower and can be traced two or three miles northwest of Mooresville, in township 14 north, 1 east, where they ceased to be noticeable. Between this spur and White River the country is gently rolling and covered to some depth with glacial material.

On the east side of the river most of the bottom land is found. It varies from a few hundred yards to three-quarters of a mile in width. The hills are not as high as on the west side and gradually become lower as they run northward. In section 2, township 13 north, 2 east, the last hill is found; at Waverly, two miles southeast, there is a sandstone quarry of typical "Knob" sandstone.

This northern portion is a good example of the gradual encroachment of drift material over the residual rock and soil.

In the accompanying map an attempt has been made to give a general idea of the location of the escarpment. The scale is too small to show only the larger valleys. The foothills are indicated by short contour lines somé distance apart. No attempt has been made to show the height of the hills by a definite number of contours.


MORGAN
JOHNSON
SHELBY
MONROE
BROWN
BARTHOLOMEW
DECATUR
JACKSON
JENNINGS
LAWRENCE
SCOTT
ORANGE
WASHINGTON
CLARK
FLOYD
HARRISON
THE EASTERN ESCARPMENT OF THE KNOBSTONE FORMATION
IN INDIANA
BY
OF THE
INDIANA UNIVERSITY GEOLOGICAL SURVEY

AN OLD SHORELINE. BY D. W. DENNIS.

The Elkhorn is a small tributary to the Whitewater River from the east, some four miles south of Richmond, Ind. There is in this stream a falls some twenty feet in height that has receded and left a gorge of about that depth for a distance of a half mile or more; this gorge is cut through strata of the same age as those through which the Niagara gorge passes. At the Elkhorn the surface rock is the Niagara limestone; it is massive and some twelve feet thick; it is underlaid by the uppermost layers of the Lower Silurian formation, consisting of alternating layers of thin flagstones and clay. This clay and fragile flags wear faster than the overlying massive rock, and so it shelves over; one can pass behind and around the falls just as he can parts of the Niagara Falls. The fossils in the Lower Silurian strata are the same one finds in the gorge at Richmond. In the uppermost stratum, however, they are beach-worn, ground in many instances to unrecognizable fragments; a half dozen species can, however, be made out—enough to settle the question of its age without dispute; it is Lower Silurian; it is an ancient coquina rock; it crops out for a distance of half a mile; tons of it can be examined; its story is as interesting as it is unmistakable; here was the beach of the Cincinnati Silurian Island; the wearing of the stones has not been in recent geological times, for they are restratified and are overlaid by the Niagara rock, which bears glacial striæ on its surface. After these rocks were beach-worn, the sea deepened, the shore line moved eastward and remained there long enough for the twelve feet of Niagara rock to form in a clear—clayless—sea.

TWO CASES OF VARIATION OF SPECIES WITH HORIZON. BY D. W. DENNIS.

The east fork of the Whitewater River has worn a gorge in the upper strata of the Lower Silurian limestone, near Richmond, Ind. This gorge is about 75 feet deep, is terminated by a falls a half mile above the city, and for a distance of some two miles below the falls the river bluffs are generally precipitous. This Lower Silurian formation consists of flagstones four inches or less in thickness, alternating with clay strata of about the same thickness. The flags are made up chiefly of the shells

of brachiopods, and these are in many places numerous in the accompanying clay strata; from these clay strata the shells weather out perfectly. This note concerns itself with two species of these brachiopods—Orthis biforata and Orthis occidentalis. The first of these has its hinge line sometimes greatly prolonged, as in Fig. (1). Every gradation in this respect is to be found as shown in Figs. (2), (3), (4) and (5). Specimens like Fig. (1) are to be found in the uppermost strata, and those with the hinge line less and less prolonged are found in lower and lower strata until finally in the lowest strata those without any prolongation—Fig. (5)—are to be found. The matter of interest is that the development of the hinge line went forward during the entire time of the formation of these rocks; its development is roughly in proportion to the altitude.

Forms like Figs. 4 and 5 continued to survive and are found at all horizons, but forms like Fig. 1 are not to be found at the lower horizons.

A similar change is to be noticed in Orthis occidentalis. Typical specimens of this species found at a low horizon have a channel along the middle line from the umbo to the anterior margin; see Fig. 6. But as one searches in higher and higher strata he finds the channel dying out and a ridge taking its place, until in the highest strata the typical species is displaced by its variety, Orthis sinuata, Fig. 7.

Notes on the Distribution of the Knobstone Group in Indiana.

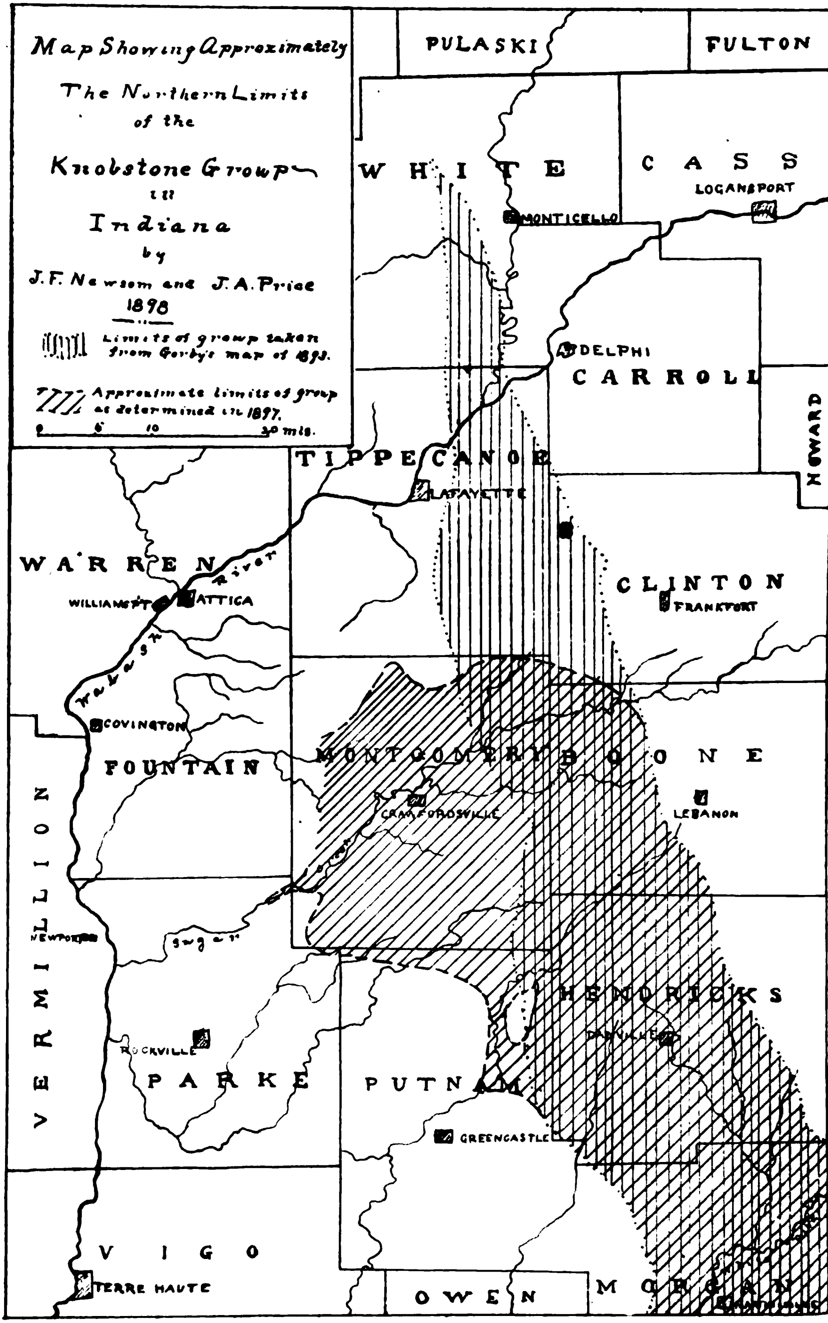
By J. F. Newsom and J. A. Price.

[Abstract.]

The series of shales and sandstones in Indiana known as the "Knobstone" has been grouped to itself principally because of its lithological characters. Because of its stratigraphical position with regard to the Lower Carboniferous limestones it has been regarded, in part at least, as the equivalent of the Kinderhook group of Illinois.

On Gorby's geological map of Indiana, of 1893, the Knobstone area is represented as extending as far northward as Honey Creek Township, in White County.

Field work done by the Indiana University Geological Survey in 1897 shows that the area underlain by the Knobstone does not extend so far north of Putnam County as has been hitherto suspected. It also seems


Map Showing Approximately
The Northern Limits
of the
Knobstone Group
in
Indiana
by
J. F. Newsom and J. A. Price
1898
Limits of group taken from Gorby's map of 1893.
Approximate limits of group as determined in 1897.
0 5 10 20 mls.
PULASKI
FULTON
WHITE
MONTICELLO
CASS
LOGANSPORT
DELPHI
CARROLL
HOWARD
TIPPECANOE
LAFAYETTE
WARREN
WILLIAMSPT
ATTICA
Wabash River
CLINTON
FRANKFORT
COVINGTON
FOUNTAIN
MONTGOMERY
CRAWFORDSVILLE
BOONE
LEBANON
VERMILLION
NEWPORT
Sugar
HENDRICKS
DANVILLE
ROCKVILLE
PARKE
PUTNAM
GREENCASTLE
VIGO
TERRE HAUTE
OWEN
MORGAN

to show that the Crawfordsville crinoid beds, which have been regarded as belonging to the Keokuk, are the statigraphical equivalents of the Knobstone strata farther south.

The accompanying map shows the area covered by the Knobstone group, north of Morgan County, as that area is given on Gorby's geological map of 1893. It shows also (approximately) the area in and north of Putnam County as the field work of 1897 indicates it to be.

It will be noticed that (as worked out by the University Survey of 1897) no Knobstone is represented as occurring north of Montgomery County, while by far the larger part of that county is underlain by it.

Small isolated areas of the Knobstone may exist north of Montgomery County, but these will in all probability be found to be only outliers.

The limits of the area, as changed from Gorby's map of 1893, are only approximate. The whole region being covered over by glacial drift, except in the deepest creek valleys, makes it necessary to trace the contacts largely by well sections. It is consequently impossible to trace them more than approximately.

Some Indiana Mildews.* By M. A. Brannon.

Four years ago a paper on "Mildews of Indiana" was presented to you by Mr. J. N. Rose, of Wabash College. His was the first step toward determining the various species of Indiana mildews. The few species, and their hosts, named in this paper are the second attempt, I believe, in this State in the direction of determining these interesting parasites, which are everywhere abundant.

To Rose's list, containing the names of eleven species and twenty-nine hosts, are added several hosts for some of the species mentioned by him, also nine species and ten hosts not found in his list.

Bessey's "Erysiphe of the United States;" Cook's "Hand-Book of British Fungi;" Bull. of the Ill. State Laboratory of Nat. History, Vol. II., and Rose's "Mildews of Indiana" were the guides used in determining and describing the following species.

Sphærotheca Castagnei Lév.

*Paper read before the Indiana Academy of Science, 1889, and heretofore unpublished.

Found on leaves of Prænanthes altissima. Rose's additional notes to Cooke's description of this form do not state that some perithecia contain two asci. Such a case was observed in two or three perithecia of this species found on an Erigeron. In these unusual forms one ascus was much larger than its companion, but not as large as the ascus existing alone in a perithecium. A few of these unusual forms might lead to the questioning of what has, heretofore, been considered a strong generic difference between a Sphærotheca and an Erysiphe.

Podosphæra oxacantha DC. was found on cherry leaves. This species was named Podosphæra Kunzei by Dr. Bessey, but the reasons for changing to P. oxacantha are detailed in Bot. Gazette, Vol. XI, page 60, 1886.

Phyllactina suffulta Reb. (P. guttata Lév.).

Found sparingly on leaves of a Desmodium.

Uncinula flexuosa.

Occurred abundantly on leaves of the buckeye. This is a beautiful species and is characterized by wavy outlines of appendages at their extremities. It is amphigenous, appendages are hyaline, varying from thirty-six to fifty-six in number; asci, seven to twelve; spores, six to ten, and strongly pedicellate.

Uncinula Ampelopsidis Pk. was found in abundance on leaves of Ampelopsis quinquefolia. In the Trans. Albany Inst., Vol. VII, page 216, Peck includes U. Americana, U. spiralis and U. subfusca under the one name of Uncinula Ampelopsidis.

Uncinula adunca Lév.

Found very abundantly on willow leaves. It is amphigenous; has six to eight asci, and usually from four to six spores, rarely eight, in our species, though Bessey describes it with only four spores.

Uncinula circinnata C. and P.

On silver maple leaves.

Microsphæra Ravenelii B.

On leaves of honey locust. The repeated forking at the apices of the appendages makes the determination of this species very easy. It has from eight to sixteen appendages; asci, four to nine; spores, six to eight.

Microsphæra extensa C. and P.

Found on the upper surface of red oak leaves and on both sides of leaves from a young oak; the species was somewhat doubtful. Both specimens had very long appendages; from four to five asci; four to eight

spores. A peculiarity was observed in the appendages of the perithecia borne on the leaves of the young oak. In many of the appendages were found swollen places resembling knee-like joints. These swellings were rather promiscuously arranged, having neither a definite location nor number on any appendage, which led to the opinion that the swellings were caused by some foreign growth. Closer observation revealed a mycelium running lengthwise the appendages and enlarging at the swollen places. This mycelium was observed, in one case, leaving the appendage and growing free from the host. Another view gave a mycelial thread of this same parasite, which, having twined itself about the apices of two appendages, was evidently drawing them together as if attempting to effect some way of reproducing itself, as is the custom of certain secondary parasites. This mycelium bore the same characteristic enlargements noted in the mycelium growing within the appendages. It acted and appeared, in many respects, like that parasite described and named Cincinobolus Cesatii by DeBary ("Die Pilze," p. 268), with this exception: He found this smaller parasite in the mycelium of mildews and not in the appendages of their perithecia. As it has been known to enter and develop its spores in the conidial chain, we may easily believe that it could make this further advance and take up its abode in the perithecia and their appendages. Granting that this secondary parasite may possibly be C. Cesatii, we have yet to dispose of the swellings borne on its mycelium. These swellings in no way resembled the reproductive organs of C. Cesatii figured and described by DeBary. They appear as internal growths of some other plant. It has been questioned whether these swellings may not be bacteroid forms existing on a secondary parasite of a primary parasite, thus giving the gradation of primary, secondary and tertiary parasitism. If so, it is desirable to allow the last two to remain in their epiparasitic habits and thus, as suggested by a German botanist (Thümen, "Pilze des Weinstocks," p. 178), they may exercise a restraining influence upon the first; and doubtless Cincinobolus does prevent the mildew from attaining its usual vigorous hold on the host plant. C. Cesatii has been found in the mycelium of some Erysiphe and Podosphæra species, but never, so far as could be learned, has it been found in an appendage nor in any part of a Microsphæra species, unless this be such a case.

Microsphæra densissima C. and P.

Very abundant on the oak leaf. This is a remarkably beautiful species growing its mycelium in orbicular and stellate patches, which enable one to recognize it at a glance.

Microsphæra diffusa C. and P.

On Desmodium leaves.

Erysiphe lamprocarpa (Wall.) Lév.

Found on many hosts, notably on Compositæ.

In addition to the host mentioned by Rose are added Aster cordifolius, Aster undulatus, Ambrosia trifida and Verbena stricta. In one instance a few asci were found containing three spores, which is contrary to what has formerly been regarded a strong specific character. This variableness of spores led to another classification of this species by Burrill and Earle (Bull. Ill. State Lab. Nat. History, Vol. II, p. 404).

Erysiphe Euphorbiæ Peck.

On Euphorbia corollata. The host bearing this species was in a withered and very sickly condition, whether from action of the mildew could not be affirmed.

Erysiphe communis (Wall.) Schl.

On Ranunculus recurvatus and an aster growing in the same place which had probably received the mildew from its neighbors. The appendages of the perithecium found on Ranunculus were fifteen to thirty-five in number and two to four times the diameter of the perithecia in length.

Erysiphe tortilis (Wall.) Lk.

On Clematis Virginiana. This species has been found on this host several times, but this specimen differed from all others described in apparently not affecting the host, which was in a vigorous condition, though the mildew was very abundant on its leaves.

Erysiphe horridula Lév.

On Verbena stricta and Eupatorium purpureum. It was difficult to decide whether this was E. horridula or E. lamprocarpa, as it closely resembles the latter, with the exception of having three to four spores in every ascus.

Recent research with improved instruments reveals many facts unknown to the early mycologists who made the first classification of mildews. Many of the characteristics forming generic and specific distinctions in their classification are found to be changeable and not always

reliable, i. e., a Sphærotheca having two asci in a perithecium or an Erysiphe lamprocarpa having more than two spores in an ascus will not harmonize with a classification denying such variableness. Hence revisions are constantly being made, which have new characteristics as bases for new classifications, or extend the limits of these formerly too restricted species. But whatever advances may be made, the revisions must retain much of the old in the development of the new, for the first classification was correct in the main, and can be altered only in respect to details based on the more minute structure revealed by further investigation with greatly improved apparatus.

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Proceedings of the INDIANA ACADEMY OF SCIENCE

1899

PROCEEDINGS

OF THE

Indiana Academy of Science

1899.

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AN ACT TO PROVIDE FOR THE PUBLICATION OF THE REPORTS AND PAPERS OF THE INDIANA ACADEMY OF SCIENCE.

[Approved March 11, 1895.]

Preamble.

WHEREAS, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State, and,

WHEREAS, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form, and,

WHEREAS, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement, therefore,

Publication of the reports of the Indiana Academy of Science.

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana,* That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided, shall be published by and under the direction of the Commissioners of Public Printing and Binding.

Editing reports.

SEC. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Academy of Science, who shall not, by reason of such services, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports, shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery. Not less than 1,500 nor more than 3,000 copies of each of said reports shall be published, the size of the edition within said limits, to be determined by the

Number of printed reports.

concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894. Proviso.

SEC. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through it editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Indiana Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture. Disposition of reports.

SEC. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage. Emergency.

AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

[Approved March 5, 1891.]

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana*, That it shall be unlawful for any person to kill any wild bird other than a game bird, or purchase, offer for sale any such wild bird after it has been killed, or to destroy the nests or the eggs of any wild bird. Birds.

SEC. 2. For the purpose of this act the following shall be considered game birds; the Anatidæ, commonly called swans, geese, brant, and river and sea ducks; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly known as shore birds, plovers, surf birds, snipe, woodcock and sandpipers, tattlers and curlews; the Gallinæ, commonly known as wild turkeys, grouse, prairie chickens, quail, and pheasants, all of which are not intended to be affected by this act.

Game birds.

SEC. 3. Any person violating the provisions of Section 1 of this act shall, upon conviction, be fined in a sum not less than ten nor more than fifty dollars, to which may be added imprisonment for not less than five days nor more than thirty days.

Penalty.

SEC. 4. Sections 1 and 2 of this act shall not apply to any person holding a permit giving the right to take birds or their nests and eggs for scientific purposes, as provided in Section 5 of this act.

Permits.

SEC. 5. Permits may be granted by the Executive Board of the Indiana Academy of Science to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to said Board written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege and pay to said Board one dollar to defray the necessary expenses attending the granting of such permit, and must file with said Board a properly executed bond in the sum of two hundred dollars, signed by at least two responsible citizens of the State as sureties. The bond shall be forfeited to the State and the permit become void upon proof that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section and shall further be subject for each offense to the penalties provided in this act.

Permits to Science.

Bond.

Bond forfeited.

SEC. 6. The permits authorized by this act shall be in force for two years only from the date of their issue, and shall not be transferable.

Two years.

SEC. 7. The English or European House Sparrow (Passer domesticus), crows, hawks, and other birds of prey are not included among the birds protected by this act.

Birds of prey.

SEC. 8. All acts or parts of acts heretofore passed in conflict with the provisions of this act are hereby repealed. Acts repealed.

SEC. 9. An emergency is declared to exist for the immediate taking effect of this act, therefore the same shall be in force and effect from and after its passage. Emergency.

TAKING FISH FOR SCIENTIFIC PURPOSES.

Section 2, Chapter XXX, Acts of 1899, page 45, makes the following provision for the taking of fish for scientific purposes: "Provided, That in all cases of scientific observation he [the Commissioner of Fisheries and Game] shall require a permit from the Indiana Academy of Science."

OFFICERS, 1899–1900.

President,

D. W. DENNIS.

Vice-President,

M. B. THOMAS.

Secretary,

JOHN S. WRIGHT.

Assistant Secretary.

E. A. SCHULTZE.

Press Secretary,

GEO. W. BENTON.

Treasurer,

J. T. SCOVELL.

EXECUTIVE COMMITTEE.

D. W. Dennis,
M. B. Thomas,
John S. Wright,
E. A. Schultze,
G. W. Benton,
J. T. Scovell,
C. A. Waldo,
C. H. Eigenmann,
Thomas Gray,
Stanley Coulter,
Amos W. Butler,
W. A. Noyes,
J. C. Arthur,
J. L. Campbell,
O. P. Hay,
T. C. Mendenhall,
John C. Branner,
J. P. D. John,
John M. Coulter,
David S. Jordan.

CURATORS.

BOTANY	J. C. Arthur.
ICHTHYOLOGY	C. H. Eigenmann.
HERPETOLOGY MAMMALOGY ORNITHOLOGY	Amos W. Butler.
ENTOMOLOGY	W. S. Blatchley.

COMMITTEES, 1899-1900.

PROGRAM.

L. J. Rettger, Severance Burrage.

MEMBERSHIP.

Donaldson Bodine, J. F. Thompson, Mel. T. Cook.

NOMINATIONS.

Katherine E. Golden, J. L. Campbell, D. M. Mottier.

AUDITING.

W. A. Noyes, W. S. Blatchley.

STATE LIBRARY.

A. W. Butler, W. A. Noyes, C. A. Waldo, J. S. Wright.

LEGISLATION FOR THE RESTRICTION OF WEEDS.

J. C. Arthur, Stanley Coulter, J. S. Wright.

PROPAGATION AND PROTECTION OF GAME AND FISH.

C. H. Eigenmann, A. W. Butler, W. S. Blatchley.

EDITOR.

Geo. W. Benton, 525 N. Pennsylvania St., Indianapolis.

DIRECTORS OF BIOLOGICAL SURVEY.

C. H. Eigenmann, V. F. Marsters, J. C. Arthur.

RELATIONS OF THE ACADEMY TO THE STATE.

C. A. Waldo, A. W. Butler, R. W. McBride.

GRANTING PERMITS FOR COLLECTING BIRDS AND FISHES.

A. W. Butler, Stanley Coulter, W. S. Blatchley.

DISTRIBUTION OF THE PROCEEDINGS.

A. W. Butler, J. S. Wright, G. W. Benton.

OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

	President.	Secretary.	Asst. Secretary.	Press Secretary.	Treasurer.
1885-6	David S. Jordan	Amos W. Butler			O. P. Jenkins.
1886-7	John M. Coulter	Amos W. Butler			O. P. Jenkins.
1887-8	J. P. D. John	Amos W. Butler			O. P. Jenkins.
1888-9	John C. Branner	Amos W. Butler			O. P. Jenkins.
1889-90	T. C. Mendenhall	Amos W. Butler			O. P. Jenkins.
1890-1	O. P. Hay	Amos W. Butler			O. P. Jenkins.
1891-2	J. L. Campbell	Amos W. Butler			C. A. Waldo.
1892-3	J. C. Arthur	Amos W. Butler	Stanley Coulter. W. W. Norman.		C. A. Waldo.
1893-4	W. A. Noyes	C. A. Waldo	W. W. Norman		W. P. Shannon.
1894-5	A. W. Butler	John S. Wright	A. J. Bigney		W. P. Shannon.
1895-6	Stanley Coulter	John S. Wright	A. J. Bigney		W. P. Shannon.
1896-7	Thomas Gray	John S. Wright	A. J. Bigney		W. P. Shannon.
1897-8	C. A. Waldo	John S. Wright	A. J. Bigney	Geo. W. Benton	J. T. Scovell.
1898-9	C. H. Eigenmann	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.
1899-1900	D. W. Dennis	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.

CONSTITUTION.

ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, the State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

SEC. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars, and thereafter an annual fee of one dollar. Any person who shall at one time

contribute fifty dollars to the funds of this Academy, may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a president, vice-president, secretary, assistant secretary, press secretary, and treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-presidents of the Academy, shall constitute an executive committee. The president shall, at each annual meeting appoint two members to be a committee which shall prepare the programmes and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the executive committee. There shall also be a summer meeting at such time and place as may be decided upon by the executive committee. Other meetings may be called at the discretion

of the executive committee. The past presidents, together with the officers and executive committee, shall constitute the Council of the Academy, and represent it in the transaction of any necessary business not specially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

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1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The president shall deliver a public address on the evening of one of the days of the meeting at the expiration of his term of office.

3. The press secretary shall attend to the securing of proper newspaper reports of the meetings and assist the secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the president and countersigned by the secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

MEMBERS.

FELLOWS.

R. J. Aley	*1898	Bloomington.
J. C. Arthur	1893	Lafayette.
P. S. Baker	1893	Greencastle.
George W. Benton	1896	Indianapolis.
A. J. Bigney	1897	Moore's Hill.
A. W. Bitting	1897	Lafayette.
Donaldson Bodine	1899	Crawfordsville.
W. S. Blatchley	1893	Indianapolis.
J. C. Branner	1893	Stanford University, Cal.
H. L. Bruner	1899	Irvington.
Wm. Lowe Bryan	1895	Bloomington.
Severance Burrage	1898	Lafayette.
A. W. Butler	1893	Indianapolis.
J. L. Campbell	1893	Crawfordsville.
John M. Coulter	1893	Chicago, Ill.
Stanley Coulter	1893	Lafayette.
Glenn Culbertson	1899	Hanover.
D. W. Dennis	1895	Richmond.
C. R. Dryer	1897	Terre Haute.
A. Wilmer Duff	1896	Lafayette.
C. H. Eigenmann	1893	Bloomington.
A. L. Foley	1897	Bloomington.
Katherine E. Golden	1895	Lafayette.
M. J. Golden	1899	Lafayette.
W. F. M. Goss	1893	Lafayette.
Thomas Gray	1893	Terre Haute.
A. S. Hathaway	1895	Terre Haute.
O. P. Hay	1893	Washington, D. C.
Robert Hessler	1899	Connersville.
H. A. Huston	1893	Lafayette.
J. P. D. John	1893	Greencastle.
D. S. Jordan	1893	Stanford University, Cal.
Arthur Kendrick	1898	Terre Haute.
Robert E Lyons	1896	Bloomington.
V. F. Marsters	1893	Bloomington.
C. L. Mees	1894	Terre Haute.
T. C. Mendenhall	1893	Worcester, Mass.
Joseph Moore	1896	Richmond.

*Date of election.

D. M. Mottier	*1893	Bloomington.
W. A. Noyes	1893	Terre Haute.
L. J. Rettger	1896	Terre Haute.
J. T. Scovell	1894	Terre Haute.
Alex. Smith	1893	Chicago, Ill.
W. E. Stone	1893	Lafayette.
Joseph Swain	1898	Bloomington.
M. B. Thomas	1893	Crawfordsville.
L. M. Underwood	1893	New York City.
C. A. Waldo	1893	Lafayette.
F. M. Webster	1894	Wooster. Ohio.
H. W. Wiley	1895	Washington, D. C.
John S. Wright	1894	Indianapolis.

NON-RESIDENT MEMBERS.

M. A. Brannon	Grand Forks, N. D.
D. H. Campbell	Stanford University, Cal.
B. W. Evermann	Washington, D. C.
Charles H. Gilbert	Stanford University, Cal.
C. W. Green	Stanford University, Cal.
C. W. Hargitt	Syracuse, N. Y.
Edward Hughes	Stockton, Cal.
O. P. Jenkins	Stanford University, Cal.
J. S. Kingsley	Tufts College, Mass.
D. T. MacDougal	Bronx Park, New York City.
Alfred Springer	Cincinnati, Ohio.
Robert B. Warder	Washington, D. C.
Ernest Walker	Clemson College, S. C.

ACTIVE MEMBERS.

G. A. Abbott	Duluth, Minn.
Frederick W. Andrews	Bloomington.
George H. Ashley	Indianapolis.
Edward Ayres	Lafayette.
Timothy H. Ball	Crown Point.
J. A. Bergström	Bloomington.
Edwin M. Blake	Lafayette.
Lee F. Bennett	Valparaiso.
M. C. Bradley	Bloomington.
Fred J. Breeze	Pittsburg.
Frank P. Bronson	Indianapolis.

* Date of election.

O. W. Brown ....Richmond.
A. Hugh Bryan ....Lafayette.
E. J. Chansler ....Bicknell.
Walter W. Chipman ....Warsaw.
George Clements ....Crawfordsville.
Charles Clickener ....Tangier.
Mel. T. Cook ....Greencastle.
U. O. Cox ....Mankato, Minn.
William Clifford Cox ....Columbus.
Albert B. Crowe ....Ft. Wayne.
M. E. Crowell ....Franklin.
Will Cumback ....Greensburg.
Edward Roscoe Cummings ....Bloomington.
Alida M. Cunningham ....Alexandria.
Martha Doan ....Westfield.
J. P. Dolan .... Syracuse.
Herman B. Dorner ....Lafayette.
Hans Duden ....Indianapolis.
Joseph Eastman ....Indianapolis.
E. G. Eberhardt ....Indianapolis.
M. N. Elrod ....Columbus.
F. L. Emory ....Morgantown, W. Va.
Percy Norton Evans ....Lafayette.
Samuel G. Evans ....Evansville.
J. E. Ewers ....
Carlton G. Ferris ....Big Rapids, Mich.
E. M. Fisher ....Urmeyville.
Austin Funk ....New Albany.
Robert G. Gillum ....Terre Haute.
Vernon Gould ....Rochester.
J. C. Gregg ....Brazil.
Alden H. Hadley ....Richmond.
U. S. Hanna ....Bloomington.
William M. Heiney ....Huntington.
Robert Hessler ....Connersville.
J. A. Hill ....
Frank C. Higgins ....Terre Haute.
Lucius M. Hubbard ....South Bend.
Alex. Johnson ....Ft. Wayne.
W. B. Johnson ....Franklin.
Ernest E. Jones ....Kokomo.
Chancey Juday ....Bloomington.
William J. Karslake ....Irvington.
D. S. Kelley ....Jeffersonville.
O. L. Kelso ....Terre Haute.

A. M. Kenyon .... Lafayette.
Ernest I. Kizer.................................... South Bend.
Charles T. Knipp .... Bloomington.
Thomas Large .... Urbana, Ill.
John Levering .... Lafayette.
V. H. Lockwood .... Indianapolis.
William A. Macbeth .... Terre Haute.
Robert Wesley McBride .... Indianapolis.
Rousseau McClellan.................................... Indianapolis.
G. W. Martin.................................... Nashville, Tenn.
Julius B. Meyer.................................... Lafayette.
O. M. Meyncke .... Brookville.
W. G. Middleton.................................... Richmond.
John A. Miller.................................... Bloomington.
W. J. Moenkhaus .... Huntingburg.
H. T. Montgomery .... South Bend.
J. P. Naylor.................................... Greencastle.
Charles E. Newlin.................................... Irvington.
John F. Newsom .... Stanford University, Cal.
E. W. Olive .... Indianapolis.
D. A. Owen.................................... Franklin.
Rollo J. Peirce.................................... Logansport.
W. H. Peirce .... Chicago, Ill.
Ralph B. Polk .... Greenwood.
James A. Price.................................... Ft. Wayne.
Frank A. Preston .... Indianapolis.
A. H. Purdue.................................... Fayetteville, Ark.
Ryland Ratliff .... Fairmount.
Claude Riddle .... Lafayette.
D. C. Ridgley.................................... Chicago, Ill.
Curtis A. Rinson .... Bloomington.
Giles E. Ripley .... Muncie.
George L. Roberts.................................... Greensburg.
D. A. Rothrock .... Bloomington.
John F. Schnaible .... Lafayette.
E. A. Schultze .... Ft. Wayne.
Howard Schurmann .... Indianapolis.
John W. Shepherd .... Terre Haute.
Claude Siebenthal.................................... Indianapolis.
J. R. Slonaker .... Bloomington.
Richard A. Smart .... Lafayette.
Lillian Snyder .... Lafayette.
William Stewart .... Lafayette.
J. M. Stoddard.................................... Crawfordsville.
Charles F. Stegmaier .... Greensburg.

Frank B. Taylor	Ft. Wayne.
S. N. Taylor	West Lafayette.
Erastus Test	Lafayette.
F. C. Test	Chicago, Ill.
J. F. Thompson	Richmond.
A. L. Treadwell	Oxford, Ohio.
Daniel J. Troyer	Goshen.
A. B. Ulrey	North Manchester.
E. Van Brumbaugh	Crawfordsville.
W. B. Van Gorder	Worthington.
Arthur C. Veatch	Rockport.
H. S. Voorhees	Brookville.
J. H. Voris	Huntington.
Fred C. Whitcomb	Delphi.
William M. Whitten	South Bend.
Guy Wilson	Greencastle.
Mae Woldt	Indianapolis
William Watson Woollen	Indianapolis.
A. J. Woolman	Duluth, Minn.
J. F. Woolsey	Indianapolis.
A. C. Yoder	Vincennes.
O. B. Zell	Clinton.

Fellows	52
Non-resident members	13
Active members	121
Total	186

LIST OF FOREIGN CORRESPONDENTS.

AFRICA.

Dr. J. Medley Wood, Natal Botanical Gardens, Berea Durban, South Africa.

South African Philosophical Society, Cape Town, South Africa.

ASIA.

China Branch Royal Asiatic Society, Shanghai, China.

Asiatic Society of Bengal, Calcutta, India.

Geological Survey of India, Calcutta, India.

Indian Museum of India, Calcutta, India.

India Survey Department of India, Calcutta, India.

Deutsche Gesellschaft für Natur- und Völkerkunde Ostasiens, Tokio, Japan.

Imperial University, Tokio, Japan.

Koninklijke Naturkundige Vereeniging in Nederlandsch-Indie, Batavia, Java.

Hon. D. D. Baldwin, Honolulu, Hawaiian Islands.

EUROPE.

V. R. Tschusizu Schmidhoffen, Villa Tannenhof, Halle in Salzburg, Austria.

Herman von Vilas, Innsbruck, Austria.

Ethnologische Mittheilungen aus Ungarn, Budapest, Austro-Hungary.

Mathematische und Naturwissenschaftliche Berichte aus Ungarn, Budapest, Austro-Hungary.

K. K. Geologische Reichsanstalt, Vienne (Wien), Austro-Hungary.

K. U. Naturwissenschaftliche Gesellschaft, Budapest, Austro-Hungary.

Naturwissenschaftlich-Medizinischer Verein in Innsbruck (Tyrol), Austro-Hungary.

Editors "Termeszetrajzi Fuzetk," Hungarian National Museum, Budapest, Austro-Hungary.

Dr. Eugen Dadai, Adj. am Nat. Mus., Budapest, Austro-Hungary.

Dr. Julius von Madarasz, Budapest, Austro-Hungary.

K. K. Naturhistorisches Hofmuseum, Vienna (Wien), Austro-Hungary.

Ornithological Society of Vienna (Wien), Austro-Hungary.

Zoologische-Bontanische Gesellschaft in Wien, Vienna, Austro-Hungary.

Dr. J. von Csato, Nagy Enyed, Austro-Hungary.

Malacological Society of Belgium, Brussels, Belgium.

Royal Academy of Science, Letters and Fine Arts, Brussels, Belgium.

Royal Linnean Society, Brussels, Belgium.

Societé Belge de Geologie, de Palaeontologié et Hydrologie, Brussels, Belgium.

Societé Royale de Botanique, Brussels, Belgium.

Societé Geologique de Belgique, Liège, Belgium.

Prof. Christian Frederick Lutken, Copenhagen, Denmark.

Bristol Naturalists' Society, Bristol, England.

Geological Society of London, London, England.

Dr. E. M. Holmes, British Pharm. Soc'y, Bloomsbury Sq., London, W. C., England.

Jenner Institute of Preventive Medicine, London, England.

Linnean Society of London, London, England.

Liverpool Geological Society, Liverpool, England.

Manchester Literary and Philosophical Society, Manchester, England.

"Nature," London, England.

Royal Botanical Society, London, England.
Royal Geological Society of Cornwall, Penzance, England.
Royal Microscopical Society, London, England.
Zoölogical Society, London, England.
Lieut.-Col. John Biddulph, 43 Charing Cross, London, England.
Dr. G. A. Boulenger, British Mus. (Nat. Hist.), London, England.
F. DuCane Godman, 10 Chandos St., Cavendish Sq., London, England.
Hon. E. L. Layard, Budleigh Salterton, Devonshire, England.
Mr. Osbert Salvin, Hawksford, Fernshurst, Haslemere, England.
Mr. Howard Saunders, 7 Radnor Place, Hyde Park, London W., England.
Phillip L. Sclater, 3 Hanover Sq., London W., England.
Dr. Richard Bowlder Sharpe, British Mus. (Nat His.), London, England.
Prof. Alfred Russell Wallace, Corfe View, Parkstone, Dorset, England.

Botanical Society of France, Paris, France.
Ministèrie de l'Agriculture, Paris, France.
Societé Entomologique de France, Paris, France.
L'Institut Grand Ducal de Luxembourg, Luxembourg, Lux., France.
Soc. de Horticulture et de Botan. de Marseille, Marseilles, France.
Societé Linneenne de Bordeaux, Bordeaux, France.
La Soc. Linneenne de Normandie, Caen, France.
Soc. des Naturelles, etc., Nantes, France.
Zoölogical Society of France, Paris, France.
Baron Louis d'Hamonville, Meurthe et Moselle, France.
Prof. Alphonse Milne-Edwards, Rue Cuvier, 57, Paris, France.
Pasteur Institute, Lille, France.

Botanischer Verein der Provinz Brandenburg, Berlin, Germany.
Deutsche Geologische Gesellschaft, Berlin, Germany.
Entomologischer Verein in Berlin, Berlin, Germany.
Journal für Ornithologie, Berlin, Germany.
Prof. Dr. Jean Cabanis, Alte Jacob Strasse, 103 A., Berlin, Germany.
Augsburger Naturhistorischer Verein, Augsburg, Germany.
Count Hans von Berlspsen, Münden, Germany.
Braunschweiger Verein für Naturwissenschaft, Braunschweig, Germany.

Bremer Naturwissenschaftlicher Verein, Bremen, Germany.
Kaiserliche Leopoldische-Carolinische Deutsche Akademie der Naturforscher, Halle, Saxony, Germany.
Königlich-Sächsische Gesellschaft der Wissenschaften. Mathematisch-Physische Classe, Leipzig, Saxony, Germany.
Naturhistorische Gesellschaft zu Hannover, Hanover, Prussia, Germany.
Naturwissenschaftlicher Verein in Hamburg, Hamburg. Germany.
Verein für Erdkunde, Leipzig, Germany.
Verein für Naturkunde, Wiesbaden, Prussia.

Belfast Natural History and Philosophical Society, Belfast, Ireland.
Royal Dublin Society, Dublin.

Societa Entomologica Italiana, Florence, Italy.
Prof. H. H. Giglioli, Museum Vertebrate Zoölogy, Florence, Italy.
Dr. Alberto Perngia, Museo Civico di Storia Naturale, Genoa, Italy.
Societa Italiana de Scienze Naturali, Milan, Italy.
Societa Africana d' Italia, Naples, Italy.
Dell 'Academia Pontifico de Nuovi Lincei, Rome, Italy.
Minister of Agriculture, Industry and Commerce, Rome, Italy.
Rassegna della Scienze Geologiche in Italia, Rome, Italy.
R. Comitato Geologico d' Italia, Rome, Italy.
Prof. Count. Tomasso Salvadori, Zoölog. Museum, Turin, Italy.

Royal Norwegian Society of Sciences, Throndhjem, Norway.
Dr. Robert Collett, Kongl. Frederiks Univ., Christiana. Norway.

Academia Real des Sciencias de Lisboa (Lisbon), Portugal.

Comité Geologique de Russie, St. Petersburg, Russia.
Imperial Academy of Sciences, St. Petersburg, Russia.
Imperial Society of Naturalists, Moscow, Russia.

The Botanical Society of Edinburgh, Edinburgh, Scotland.
John J. Dalgleish, Brankston Grange, Bogside Sta., Sterling, Scotland.
Edinburgh Geological Society, Edinburgh, Scotland.
Geological Society of Glasgow, Scotland.
John A. Harvie-Brown, Duniplace House, Larbert, Stirlingshire, Scotland.
Natural History Society, Glasgow, Scotland.
Philosophical Society of Glasgow, Glasgow, Scotland.
Royal Society of Edinburgh, Edinburgh, Scotland.
Royal Physical Society, Edinburgh, Scotland.

Barcelona Academia de Ciencias y Artes, Barcelona, Spain.
Royal Academy of Sciences, Madrid, Spain.
Institut Royal Geologique de Suède, Stockholm, Sweden.
Societé Entomologique à Stockholm, Stockholm, Sweden.
Royal Swedish Academy of Science, Stockholm, Sweden.
Naturforschende Gesellschaft, Basel, Switzerland.
Naturforschende Gesellschaft in Berne, Berne, Switzerland.
La Societé Botanique Suisse, Geneva, Switzerland.
Societé Helvetique de Sciences Naturelles, Geneva, Switzerland.
Societé de Physique et d' Historie Naturelle de Geneva, Geneva, Switzerland.
Concilium Bibliographicum, Zürich-Oberstrasse, Switzerland.
Naturforschende Gesellschaft, Zürich, Switzerland.
Schweizerische Botanische Gesellschaft, Zürich, Switzerland.
Prof. Herbert H. Field, Zürich, Switzerland.

AUSTRALIA.

Linnean Society of New South Wales, Sidney, New South Wales.
Royal Society of New South Wales, Sidney, New South Wales.
Prof. Liveridge, F. R. S., Sidney, New South Wales.
Hon. Minister of Mines, Sidney, New South Wales.
Mr. E. P. Ramsey, Sidney, New South Wales.
Royal Society of Queensland, Brisbane, Queensland.
Royal Society of South Australia, Adelaide, South Australia.
Victoria Pub. Library, Museum and Nat. Gallery, Melbourne, Victoria.
Prof. W. L. Buller, Wellington, New Zealand.

NORTH AMERICA.

Natural Hist. Society of British Columbia, Victoria, British Columbia.
Canadian Record of Science, Montreal, Canada.
McGill University, Montreal, Canada.
Natural Society, Montreal, Canada.
Natural History Society, St. Johns, New Brunswick.
Nova Scotia Institute of Science, Halifax, N. S.
Manitoba Historical and Scientific Society, Winnepeg, Manitoba.
Dr. T. McIlwraith, Cairnbrae, Hamilton, Ontario.
The Royal Society of Canada, Ottawa, Ontario.
Natural History Society, Toronto, Ontario.
Hamilton Association Library, Hamilton, Ontario.
Canadian Entomologist, Ottawa, Ontario.
Department of Marine and Fisheries, Ottawa, Ontario.
Ontario Agricultural College, Guelph, Ontario.
Canadian Institute, Toronto.
Ottawa Field Naturalists' Club, Ottawa, Ontario.
University of Toronto, Toronto.
Geological Survey of Canada, Ottawa, Ontario.
La Naturaliste Canadian, Chicontini, Quebec.

La Naturale Za, City of Mexico.
Mexican Society of Natural History, City of Mexico.
Museo Nacional, City of Mexico.
Sociedad Cientifica Antonio Alzate, City of Mexico.
Sociedad Mexicana de Geographia y Estadistica de la Republica Mexicana, City of Mexico.

WEST INDIES.

Victoria Institute, Trinidad, British West Indies.
Museo Nacional, San Jose, Costa Rica, Central America.
Dr. Anastasia Alfaro, Secy. National Museum, San Jose, Costa Rica.
Rafael Arango, Havana, Cuba.
Jamaica Institute, Kingston, Jamaica, West Indies.

SOUTH AMERICA.

Argentina Historia Natural Florentine Amegline, Buenos Ayres, Argentine Republic.

Musée de la Plata, Argentine Republic.

Nacional Academia des Ciencias, Cordoba, Argentine Republic.

Sociedad Cientifica Argentina, Buenos Ayres.

Museo Nacional, Rio de Janeiro, Brazil.

Sociedad de Geographia, Rio de Janeiro, Brazil.

Dr. Herman von Jhering, Dir. Zoöl. Sec. Con. Geog. e Geol. de Sao Paulo, Rio Grande do Sul, Brazil.

Deutscher Wissenschaftlicher Verein in Santiago, Santiago, Chili.

Societé Scientifique du Chili, Santiago, Chili.

Sociedad Guatemalteca de Ciencias, Guatemala, Guatemala.

. . . PROGRAM . . .

OF THE

FIFTEENTH ANNUAL MEETING

OF THE

Indiana Academy of Science,

STATE HOUSE, INDIANAPOLIS.

December 27 and 28, 1899.

OFFICERS AND EX-OFFICIO EXECUTIVE COMMITTEE.

C. H. EIGENMANN, President, D. W. DENNIS, Vice-President, JOHN S. WRIGHT, Secretary.
E. A. SCHULTZE, Asst. Secretary. GEO. W. BENTON, Press Secretary.
J. T. SCOVELL, Treasurer.

C. A. WALDO,	W. A. NOYES,	O. P. HAY,	J. P. D. JOHN,
THOMAS GRAY,	J. C. ARTHUR,	T. C. MENDENHALL,	JOHN M. COULTER,
STANLEY COULTER,	J. L. CAMPBELL,	JOHN C. BRANNER,	DAVID S. JORDAN.
AMOS W. BUTLER,			

The sessions of the Academy will be held in the State House, in the rooms of the State Board of Agriculture.

Headquarters will be at the Bates House. A rate of $2.00 and up per day will be made to all persons who make it known at the time of registering that they are members of the Academy.

Reduced railroad rates for the members can not be obtained under the present ruling of the Traffic Association. Many of the colleges can secure special rates on the various roads. Those who can not do this, could join the State Teachers' Association and thus secure a one and one-third round trip fare.

M. B. THOMAS,
C. R. DRYER,
Committee.

GENERAL PROGRAM.

WEDNESDAY, DECEMBER 27.

Meeting of Executive Committee at the Hotel Headquarters .... 8 P. M.

THURSDAY, DECEMBER 28.

General Session .... 9 a. m. to 12 m.
Sectional Meetings .... 2 p. m. to 5 p. m.

LIST OF PAPERS TO BE READ.

ADDRESS BY THE RETIRING PRESIDENT,

PROFESSOR C. H. EIGENMANN,

At 10 o'clock Thursday morning.

Subject: "Degeneration Illustrated by the Eyes of the Cave Fishes."

The following papers will be read in the order in which they appear on the program, except that certain papers will be presented "*pari passu*" in sectional meetings. When a paper is called and the reader is not present, it will be dropped to the end of the list, unless by mutual agreement an exchange can be made with another whose time is approximately the same. Where no time was sent with the papers, they have been uniformly assigned ten minutes. Opportunity will be given after the reading of each paper for a brief discussion.

N. B.—By the order of the Academy, no paper can be read until an abstract of its contents or the written paper has been placed in the hands of the Secretary.

GENERAL.

1. The Florida Gopher, 30 m........................W. B. Fletcher
2. Libraries of Microscopical Slides, 5 m..................A. J. Bigney
3. A Method of Registration for Anthropological Purposes, 10 m., ...A. W. Butler

*4. A Vacation Trip to the San Marcos, Texas, Caves and Springs, 15 m..C. H. Eigenmann

*5. A New Pathogenic Yeast, 12 m.............R. Lyons and L. Rettger

6. Aids in Teaching Physical Geography, 10 m..........V. F. Marsters
7. Some Preliminary Notes on the Hygienic Value of Various Street Pavements as Determined by Bacteriological Analyses, 10 m.................Severance Burrage and D. B. Luten
8. Insects as Factors in the Spread of Bacterial Diseases, 20 m., ...Severance Burrage
9. House Boats for Biological Work, 10 m..................U. O. Cox

MATHEMATICS AND PHYSICS.

10. Tests on Some Ball and Roller Bearings, 12 m..........M. J. Golden
11. Bearing-Testing Dynamometer, 10 m..................M. J. Golden
12. The Toepler-Holtz Machine for Roentgen Rays, 5 m...J. L. Campbell

* Author absent, paper not presented.

13. A Proposed Notation for the Geometry of the Triangle, 5 m., ...R. J. Aley
14. Some Circles Connected with the Triangle, 8 m...........R. J. Aley
15. The Point P and Some of its Properties, 8 m..............R. J. Aley
*16. Applications of Group Theory, 5 m..................D. A. Rothrock
*17. Singularities of Certain Continuous Groups, 5 m......E. W. Rettger
*18. On a Family of Warped Surfaces Connected by a Simple Functional Relation, 20 m...C. A. Waldo and B. C. Waldenmaier
19. Diamond Fluorescence, 10 m............................A. L. Foley
20. Some Experiments on Locomotive Combustion, 10 m..J. W. Shepherd

CHEMISTRY.

21. Some Ionization Experiments, 10 m....................P. N. Evans
22. Synthesis of the 2-3, 3-Trimethyl cyclopentanone, a cyclic derivative of Camphor, 10 m......................W. A. Noyes

BOTANY.

23. Contributions to the Flora of Indiana, VI, 10 m......Stanley Coulter
24. Some Unrecognized Forms of Native Trees, 10 m....Stanley Coulter
25. Seedlings of Certain Native Herbaceous Plants, 10 m........ ....Stanley Coulter and Herman Dorner
26. The Resin Ducts and Strengthening Cells of Abies and Picea, 10 m ....Herman Dorner
*27. Karyokinesis in Magnolia with Special Reference to the Behavior of the Chromosomes, 10 m................F. M. Andrews
28. A Proteolytic Enzyme of Yeast, 15 m..........Katherine E. Golden
29. Saccharomyces anomalus Hausen (?), 10 m.....Katherine E. Golden
30. Some Problems in Corallorhiza, 8 m..................M. B. Thomas
31. Disappearance of Sedum ternatum, 5 m.............M. B. Thomas

ZOOLOGY.

*32. The Kankakee Salamander, 5 m.........................T. H. Ball
33. The Eye of the Mole, 5 m............................J. R. Slonaker
34. Notes on Indiana Birds, 10 m.........................A. W. Butler
35. Biological Conditions of Round and Shriner Lakes, Whitley County, Indiana, 10 m.......................E. B. Williamson

* Author absent, paper not presented.

*36. The Arthropods of the San Marcos Caves and Springs, 10 m.. .... Carl Ulrich

*37. The Retinal Pattern of Single and Double Cones in the Eyes of Fishes, 10 m................ C. H. Eigenmann and G. Shafer

*38. Some Notes on the Blind Fish Caves at Mitchell, Indiana, 5 m .... C. H. Eigenmann

39. The Eyes of Cambrus pellucidus from Mammoth Cave, 10 m .... F. M. Price

*40. The Optic Lobes of the Blind Fish, Amblyopsis, 10 m..E. E. Ramsey

*41. The Cold-Blooded Vertebrates of Winona Lake and its Vicinity, 5 m.. E. E. Ramsey

42. Cortex Cells of the Mouse's Brain, 10 m............... D. W. Dennis

*43. Cocoon Spinning in Lycosa, 5 m.................. W. J. Moenkhaus

*44. Some Hybrid Fishes, 10 m...................... W. J. Moenkhaus

GEOLOGY.

45. The Physical Geography of the Region of the Great Bend of the Wabash, 10 m........................... W. A. McBeth

46. An Interesting Bowlder, 5 m....................... W. A. McBeth

47. The Headwaters of Salt Creek in Porter County, Indiana, 10 m .... L. F. Bennett

48. Weathering and Erosion of North and of South Slopes, 8 m., ... G. Culbertson

49. A Cranium of Castoroides found at Greenfield, Indiana, 5 m., ... Joseph Moore

50. On the Waldron Fauna at Tarr Hole, Indiana, 10 m..E. R. Cumings

51. The Stream Gradients of the Lower Mohawk Valley, 10 m., ... E. R. Cumings

52. Skull of Fossil Bison, 10 m......W. G. Middleton and Joseph Moore

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*Author absent, paper not presented.

THE FIFTEENTH ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The fifteenth annual meeting of the Indiana Academy of Science was held in Indianapolis, Thursday, December 28, 1899, preceded by a session of the Executive Committee of the Academy, 9 p. m., Wednesday, December 27.

At 9 a. m., December 28, in the absence of the President, C. H. Eigenmann, Vice President D. W. Dennis called the Academy to order in general session, at which committees were appointed and other routine and miscellaneous business transacted. After the disposition of these affairs, the address of the retiring President, Dr. C. H. Eigenmann, was read by the Vice President, Dr. D. W. Dennis; subject, "Degeneration Illustrated by the Eyes of Cave Fishes." Following this address, until adjournment at 12 m., the Academy was engaged with the papers of the printed program under the title, "General Subjects."

At 2 p. m. the Academy met in two sections—biological and physico-chemical– for the reading and discussion of papers. Vice President Dennis presided over the biological section, while G. W. Benton acted as chairman of the physico-chemical section. At 5 p. m. the section meetings adjourned and the Academy was assembled in general session for the transaction of business.

Adjournment, 5:30 p. m.

THE FIELD MEETING OF 1899.

The Field Meeting of 1899 was held at Crawfordsville, Thursday, Friday and Saturday, May 25, 26 and 27.

At 8:30 p. m. Thursday, the Executive Committee met for the transaction of business.

Friday the 26th was spent in the field. Leaving Crawfordsville early in the morning, the party traveled by carriages to Pine Hills, a district which afforded excellent field opportunities to the botanists, zoologists and geologists. The return to Crawfordsville was made by way of Alamo and Yountsville. In the evening the Academy was given a reception at the residence of President Burroughs, of Wabash College.

On Saturday the members made field excursions to the north of Crawfordsville, visiting the well-known crinoid beds along Sugar Creek.

The Academy is greatly indebted to the local members for their generous and thoughtful hospitality, which was a prominent feature of the meeting.

PRESIDENT'S ADDRESS.

DEGENERATION IN THE EYES OF THE COLD-BLOODED VERTEBRATES OF THE NORTH AMERICAN CAVES.

By C. H. Eigenmann.

"Degeneration," says Lankester, "may be defined as the gradual change of the structure in which the organism becomes adapted to less varied and less complex conditions of life; whilst elaboration is a gradual change of structure in which the organism becomes adapted to more and more varied and complex conditions of existence."

Degeneration may affect the organism as a whole or some one part. I propose to speak not on degeneration in general but to give a concrete example of the degeneration of the parts of one organ.

The eyes of the blind vertebrates of North America lend themselves to this study admirably, because different ones have reached different stages in the process, so by studying them all we get a series of steps through which the most degenerate has passed, and are enabled to reach conclusions that the study of an extreme case of degeneration would not give us.

I shall confine myself to the cave salamanders and the blind fishes (Amblyopsidae) nearly all of which I have visited in their native haunts. The salamanders are introduced to illuminate some dark points in the degeneration of the eyes of the fishes and to emphasize a fact that is forcing itself forward with increasing vehemence; i. e., that cross-country conclusions are not warrantable; that the blind fishes form one group and the salamanders other groups, and that however much one may help us to understand the other, we must not expect too close an agreement in the steps of their degeneration under similar conditions.

There are three cave salamanders in North America.

1. Spelerpes maculicauda is found generally distributed in the caves of the Mississippi Valley. It so closely resembles Spelerpes longicauda that it has not, until more recent years, been distinguished from the latter, which has an even wider epigæan distribution. There is nothing about the structure of the salamander that marks it as a cave species, but its habits are conclusive.

2. Typhlotriton is much more restricted in its distribution, being confined to a few caves in southwestern Missouri. I have taken its larvae at the mouth of Rock House Cave in abundance. In the deeper recesses of Marble Cave I secured both young and adult. This is a cave species of a more pronounced type. The very habit that accounts for the presence of salamanders in caves has been retained by this one. I found some individuals hiding (?) under rocks, and in the aquarium their stereotropic nature manifests itself by the fact that they crawl into glass tubing, rubber tubing or under wire screening. In the eye of this species we have some of the early steps in the process of degeneration.

3. Typhlomolge has been taken from a surface well near San Marcos, Texas, and from the artesian well of the U. S. Fish Commission at the same place. The artesian well taps a cave stream about 190 feet from the surface. It has also been seen in the underground stream of Ezel's Cave near San Marcos. It was also reported to me from South of San Antonio, Texas. This is distinctly and exclusively a cave species, and its eyes are more degenerate than those of any other salamander, including the European Proteus.*

The Amblyopsidae are a small family of fresh-water fishes and offer exceptional facilities for the study of the steps in the degeneration of eyes. There are at least six species and we have gradations in habits from permanent epigæan species to species that have for ages been established in caves.

The species of Chologaster possess well developed eyes. One of them, C. cornutus, is found in the coast streams of the southeastern States; another, C. papilliferus, is found in some springs in southwestern Illinois, while the third, C. agassizii, lives in the cave streams of Kentucky and Tennessee.

The other members of the family are cave species with very degenerate eyes. They represent three genera which are descended from three epigæan species. Amblyopsis, the giant of the race, which reaches 135

* It may be noticed that the eyes of the western Typhlotriton are more degenerate than those of the cave Spelerpes of wider distribution. Further the eyes of the Texas Typhlomolge are more degenerate than those of the Missouri Typhlotriton. Similarly the Missouri blind fish Troglichthys has eyes in a much more advanced state of degeneration than the Ohio valley blind fishes. It is possible that the explanation is to be found in the length of time the caves in these regions have been habitable. During the glacial epoch the caves of the Ohio valley were near the northern limit of vegetation. The Missouri caves, if affected at all by glaciation, must have become habitable before those of the Ohio valley, while those of Texas were probably not affected at all.

mm. in length, is found in the caves of the Ohio Valley. Typhlichthys is also found in the Ohio valley but chiefly south of the Ohio River. But a single specimen has been found north of the Ohio, and this specimen represents a distinct species. Troglichthys, which is found in the caves of Missouri, has been in caves longer than its relatives, if the degree of the degeneration of its eyes is a criterion.

Before dealing with the degeneration of the eye a few words are in order on the normal structure of the organ under consideration.

In the normally developed eye we may distinguish a variety of parts with different functions. These are:

A. Organs for protection like the lid and orbits.

B. Organs for moving the eye to enable it to receive direct rays of light. In the cold-blooded vertebrates these consist of four rectus muscles and two oblique.

C. Organs to support the active structures, the fibrous or cartilaginous sclera.

D. The eye proper, consisting of:

1. Parts for transmitting and focusing light; the cornea, lens and vitreous body.

2. Parts for receiving light and transforming it to be transmitted to the brain; the retina.

3. A part for transmitting the converted impression to the brain; the optic nerve.

Some of these, as the muscles, retina and optic nerve, are active, while others, the dioptric, protective and supporting organs, are passive.

A. In the Amblyopsidæ the skin passes directly over the eye without forming a free orbital rim or lid. The skin over the eye in Chologaster is much thinner than elsewhere and free from pigment. In the other genera of the family the eye has been withdrawn from the surface. In these it lies deep beneath the skin, and the latter, where it passes over the eye, has assumed the structure normal to it in other parts of the head.

In the salamanders we have a perfect gradation in the matter of the eye lids. In Spelerpes a free orbital rim is present in every respect like that found in epigæan salamanders. In Typhlotriton the lids are closing over the eye. The slit between the upper and the lower lid is much shorter than usual, and the upper lid overlaps the lower. The conjunctiva is still normal. The eye of this species is midway between the

normal salamander eye and that of Typhlomolge in which a slight thinning of the skin is all there is to indicate its former modification over the eye.

B. The muscles to change the direction of the eye ball show complete gradations from perfect development to total disappearance. In the species of Chologaster all the muscles are normally developed. In Amblyopsis the muscles are unequally developed, but one or more are always present and can be traced from their origin to the eye. In Troglichthys the distal halves of the muscles, the parts nearest the eye, have been replaced by connective tissue fibers; i. e., a tendon has replaced part of the muscle. Here we have a step in advance in the degeneration found in Amblyopsis and no instance was noticed where all the muscles of any eye were even developed in the degree described. In Typhlichthys the muscles have all disappeared.

In Typhlomolge the muscles have disappeared; in the other salamanders they are present.

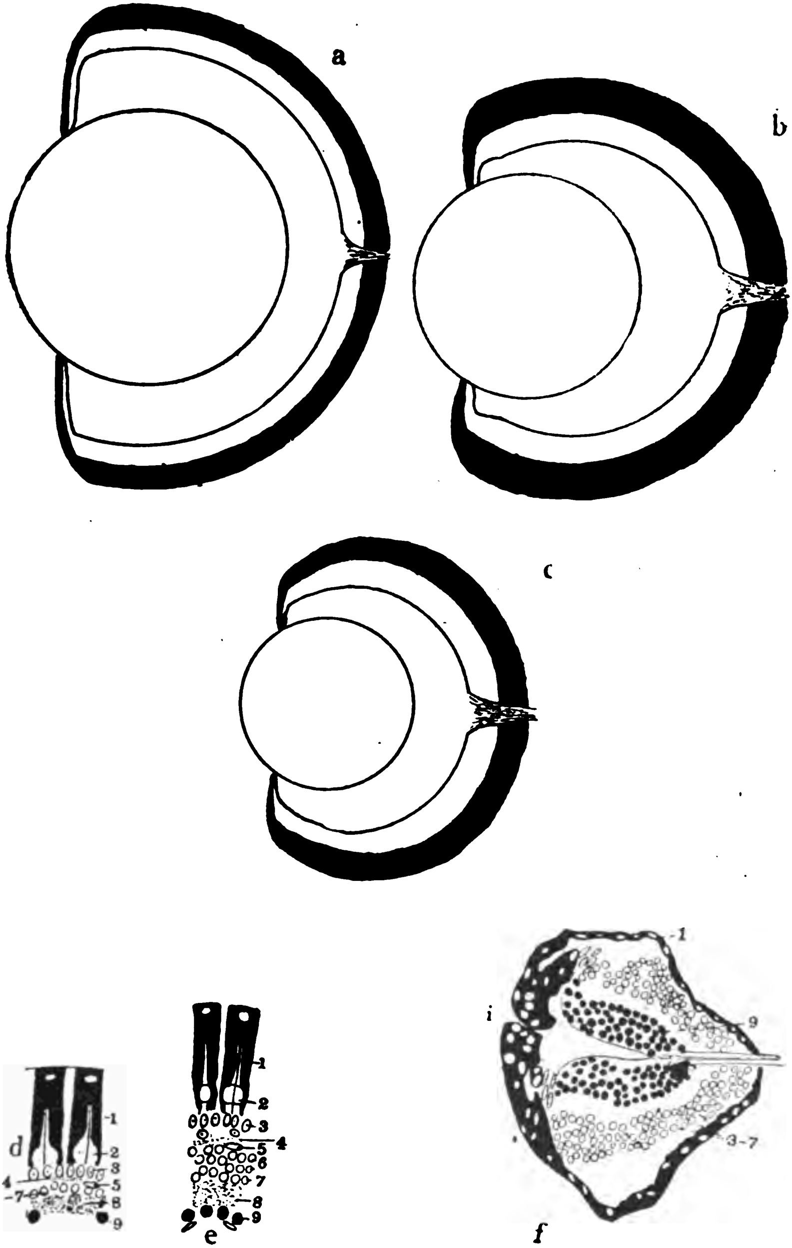
C. The sclera is indifferently developed in Chologaster and there is but little modification in the species with more degenerate eyes, except that in Amblyopsis and Troglichthys where cartilaginous bands were evidently present in the epigæan ancestors these bands have persisted in a remarkable degree, being much too large for the minute eye with which they are connected. In Troglichthys they form a hood over the front of the eye and various projections and angles in their endeavor to accommodate themselves to the small structure which they cover.

This is in striking contrast to the condition in Typhlotriton where but a single slight nodule of cartilage remains. Even this is frequently absent in the adult, while in the larvae of the same species a cartilaginous band extends almost around the equator of the eye. The different effect of degeneration in the Amblyopsidae and the salamander could not be more forcibly illustrated than by the scleral cartilages. The presence of a cartilagenous band in the young is, possibly, a larval character, and its absence in the adult has, in that case, no bearing on phylogenetic degeneration.

D. The eye as a whole and its different parts may now be considered.

1. The dioptric apparatus.

The steps in the degeneration of the eye in general are indicated in the accompanying figures.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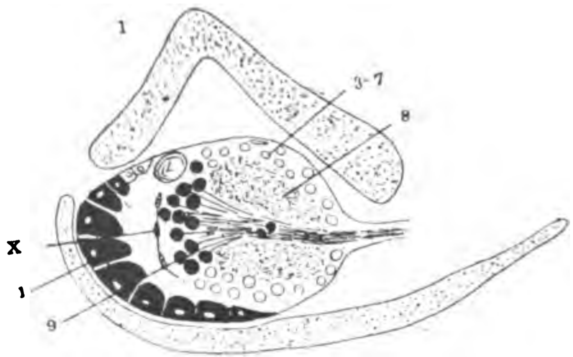

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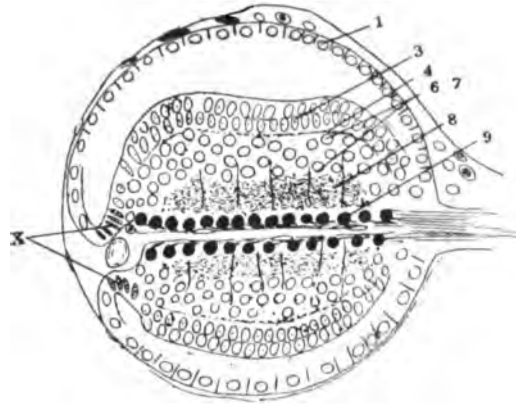

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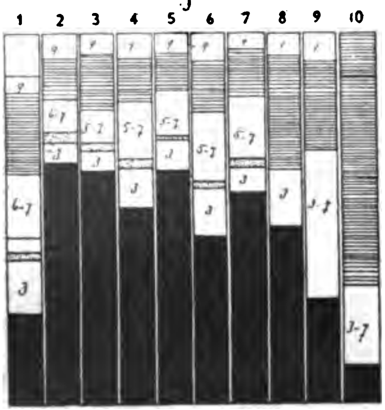

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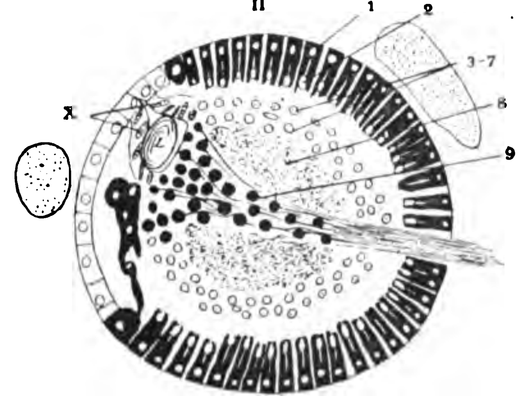

EXPLANATION OF FIGURES.

A.—I. Diagrams of the eyes of all the species of the Amblyopsidae and of Typhlomolge.

A—C, the eyes of Chologaster cornutus, papilliferus and agassizii drawn to scale.

D, E, G, H, I are drawn under the same magnification.

D.—The retina of Chologaster cornutus.

E.—The retina of Chologaster papilliferus.

F.—The eye of Typhlomolge under lower magnification.

G.—The eye of Typhlichthys subterraneus.

H.—The eye of Amblyopsis spelaeus.

I.—The eye of Troglichthys rosae.

The most highly developed eye is that of Chologaster papilliferus. The parts of this eye are well proportioned, but the eye as a whole is small, measuring less than one millimeter in a specimen 55 mm. long. The proportions of this eye are symmetrically reduced if it has been derived from a fish eye of the average size, but the retina is much simpler than in such related pelagic species as Zygonectes. The simplifications in the retina have taken place between the outer nuclear and the ganglionic layers. The pigment layer has not been materially affected. These facts are exactly opposed to the supposition of Kohl, that the retina and the optic nerve are the last to be affected and that the vitreous body and the lens cease to develop early. In Chologaster papilliferus the latter parts are normal, while the retina is simplified. That the retina is affected first is proved beyond cavil by Chologaster cornutus. The vitreous body and the lens are here larger than in papilliferus, but the retina is very greatly simplified. Cornutus, it must be borne in mind, lives in the open. The eye of the cave species Chologaster agassizii differs from that of papilliferus largely in size. There is little difference in the retinas except the pigmented layer, which is about 26 per cent. thinner in agassizii than in papilliferus.

There is a big gap between the lowest eye of Chologaster and the highest eye of the blind members of the Amblyopsidae. The lens in the latter has lost its fibrous nature and is merely an ill-defined minute clump of cells scarcely distinguishable in the majority of cases. The vitreous body of the latter species is gone with perhaps a trace still remaining in Typhlichthys. With the loss of the lens and the vitreous body the eye

collapsed so that the ganglionic layer formerly lining the vitreous cavity has been brought together in the center of the eye.

The layers of the retina in Typhlichthys are so well developed that could the vitreous body and lens be added to this eye it would stand on a higher plane than that of Chologaster cornutus exclusive of the cones. It is generally true that at first the thickness of the layers of the retina is increased as the result of the reduction of the lens and vitreous body and the consequent crowding of the cells of the retina, whose reduction in number does not keep pace with the reduction in the dioptric apparatus in total darkness.

If we bear in mind that no two of the eyes represented here are members of a phyletic series we may be permitted to state that from an eye like that of cornutus, but possessing scleral cartilages, both the eyes of Amblyopsis and Troglichthys have been derived and that the eye of Amblyopsis represents one of the stages through which the eye of Troglichthys passed. The eye of Amblyopsis is the eye of C. cornutus minus a vitreous body with the pupil closed and with a minute lens. The nuclear layers have gone a step further in their degeneration than in cornutus, but the greatest modification has taken place in the dioptric arrangements.

In Troglichthys even the mass of ganglionic cells present in the center of the eye as the result of the collapsing after the removal of the vitreous body has vanished. The pigmented epithelium, and in fact all the other layers, are represented by mere fragments.

The eye of Typhlichthys has degenerated along a different line. There is an almost total loss of the lens and vitreous body in an eye like that of papilliferus without an intervening stage like that of cornutus, and the pigment layer has lost its pigment, whereas in Amblyopsis it was retained.

The salamanders bridge the gap existing between the Chologasters and the blind members of the Amblyopsidae. But even at the risk of monotonous repetition I want again to call attention to the fact that the salamanders do not belong to the same series as the Amblyopsidae. The dioptric arrangements of Typhlotriton are all normal; the retina is normal in the young, but the rods and cones all disappear with the change from the larval to the adult condition. In Typhlomolge the lens and largely the vitreous body are gone and the eye has collapsed. The vitreous body is, however, much better represented than in the blind Amblyopsidae and the iris is, especially in the young, much better developed than in the fishes.

2. The retina.

(a) There is more variety in the degree of development of the pigment epithelium than in any other structure of the eye. Ritter has found that in Typhlogobius this "layer has actually increased in thickness concomitantly with the retardation in the development of the eye, or it is quite possible with the degeneration of this particular part of it. * * * An increase of pigment is an incident to the gradual diminution in functional importance and structural completeness." There is so much variation in the thickness of this layer in various fishes that not much stress can be laid on the absolute or relative thickness of the pigment in any one species as an index of degeneration. While the pigment layer is, relative to the rest of the retina, very thick in the species of Chologaster, it is found that the pigment layer of Chologaster is not much, if any, thicker than that of Zygonectes. Exception must be made for specimens of the extreme size in papilliferus and agassizii. In other words, primarily the pigment layer has retained its normal condition while the rest of the retina has been simplified, and there may even be an increase in the thickness of the layer as one of its ontogenic modifications. Whether the greater thickness of the pigment in the old Chologaster is due to degeneration or the greater length of the cones in a twil'ght species, I am unable to say. In Typhlichthys, which is undoubtedly derived from a Chologaster-like ancestor, no pigment is developed. The layer retains its epithelial nature and remains apparently in its embryonic condition. It may be well to call attention here to the fact that the cones are very sparingly developed, if at all, in this species. In Amblyopsis, in which the degeneration of the retina has gone further, but in which the cones are still well developed, the pigment layer is very highly developed, but not by any means uniformly so in different individuals. The pigment layer reaches its greatest point of reduction in rosae where pigment is still developed, but the layer is fragmentary, except over the distal part of the eye. We thus find a development of pigment with an imperfect layer in one case and a full developed layer without pigment in another, Typhlichthys. In the Chologasters the pigment is in part prismatic; in the other species, granular. The rods disappear before the cones.

(b) In the outer nuclear layer a complete series of steps is observable from the two-layered condition in papilliferus to the one-layered in cornutus to the undefined layer in Typhlichthys and the merging of the

nuclear layer in Amblyopsis, and their occasional total absence in rosae. The rods disappear first, the cones long before their nuclei.

(c) The outer reticular layer naturally meets with the same fate as the outer nuclear layer. It is well developed in papilliferus, evident in cornutus, developed in spots in Typhlichthys, and no longer distinguishable in the other species.

(d) The layers of horizontal cells are represented in papilliferus by occasional cells; they are rarer in cornutus and beyond these have not been detected.

(e) The inner nuclear layer of bipolar and spongioblastic cells is well developed in papilliferus. In cornutus it is better developed in the young than in the older stages where it forms but a single layer of cells. There is evidently in this species an ontogenic simplification. In the remaining species it is, as mentioned above, merged with the outer nuclear layer into one layer which is occasionally absent in Troglichthys.

(f) The inner reticular layer is relatively better developed than any of the other layers, and the conclusion naturally forces itself upon one that it must contain other elements besides fibres of the bipolar and ganglionic cells, for, in Amblyopsis and Troglichthys, where the latter are very limited or absent, this layer is still well developed. Horizontal cells have only been found in the species of Chologaster.

(g) In the ganglionic layer we find again a complete series of steps from the most perfect eye to the condition found in Troglichthys. In papilliferus the cells form a complete layer one cell deep, except where the cells have given way to the optic fibre tracts which pass in among the cells instead of over them. In cornutus the cells have been so reduced in number that they are widely separated from each other. With the loss of the vitreous cavity the cells have been brought together again into a continuous layer in Typhlichthys, although there are much fewer cells than in cornutus even. The next step is the formation of a solid core of ganglionic cells, and the final step the elimination of this central core in Troglichthys, leaving but a few cells over the anterior face of the retina.

(h) Müllerian nuclei are found in all but Amblyopsis and Troglichthys. In C. cornutus they lie in part in the inner reticular and the ganglionic layer. Cells of this sort are probably also found among the ganglionic cells of Typhlichthys.

3. The optic nerve shows a clear gradation from one end of the series of fishes to the other. In Chologaster papilliferus it reaches its maximum

development. In cornutus, which possesses an eye larger than papilliferus, but in which the ganglionic layer is simplified, the nerve is measurably thinner. In Typhlichthys the nerve can be traced to the brain even in specimens 40 mm. long; i. e., in specimens which are evidently adult. In Amblyopsis the nerve can be followed to the brain in specimens 25 mm. long, but in the adult I have never been able to follow it to the brain. In Troglichthys it has become so intangible that I have not been able to trace it for any distance beyond the eye.

We thus see that the simplification or reduction in the eye is not a horizontal process. The purely supporting structure, like the scleral cartilages have been retained out of all proportion to the rest of the eye. The pigment layer has been both quantitatively and qualitatively differently affected in different species. There was primarily an increase in the thickness of this layer, and later a tendency to total loss of pigment. The degeneration has been more uniformly progressive in all the layers within the pigment layer. The only possible exception being the inner reticular layer which probably owes its retention more to its supporting than to its nervous elements. Another exception is found in the cones, but their degree of development is evidently associated with the degree of development of the pigmented layer. As long as the cones are developed the pigmented layer is well developed or vice versa.

We find, in general, that the reduction in size from the normal fish eye went hand in hand with the simplification of the retina. There was at first chiefly a reduction in the number of many times duplicated parts. Even after the condition in Chologaster papilliferus was reached the degeneration in the histological condition of the elements did not keep pace with the reduction in number (vide the eye of cornutus). The dioptric apparatus disappeared rather suddenly and the eye as a consequence collapsed with equal suddenness in those members which, long ago, took up their abode in total darkness. The eye not only collapsed, but the number of elements decreased very much. The reduction was in the horizontally repeated elements. The vertical complexity, on which the function of the retina really depends, was not greatly modified at first.

In those species which took up their abode in total darkness the degeneration in the dioptric apparatus was out of proportion to the degeneration of the retina, while in those remaining above ground the retinal structures degenerated out of proportion to the changes in the dioptric apparatus, which, according to this view, degenerates only under condi-

tions of total disuse or total darkness, which would necessitate total disuse. This view is upheld by the conditions found in Typhlogobius, as Ritter's drawings and my own preparations show. In Typhlogobius the eye is functional in the young and remains a light-perceiving organ throughout life. The fish live under rocks between tide water (Eigenmann 90). We have here an eye in a condition of partial use, and the lens is not affected. The retina has, on the other hand, been horizontally reduced much more than in the Amblyopsidae, so that should the lens disappear, and Ritter found one specimen in which it was gone, the type of eye found in Troglichthys would be reached without passing through a stage found in Amblyopsis; it would be simply a horizontal contracting of the retina, not a collapsing of the entire eye.

The question may with propriety be asked here, Do the most degenerate eyes approach the condition of the pineal eye? It must be answered negatively.

ONTOGENIC DEGENERATION.

The developmental side of this question will be taken up with the development of the eye in Amblyopsis.

The simplification of the eye in cornutus has been mentioned in the foregoing paragraphs. It may be recalled that the nuclear layers are thinner in the old than in the young. There is here not so much an elimination or destruction of element as a simplification of the arrangements of parts, comparatively few being present to start with.

The steps in ontogenic degeneration can not be given with any degree of finality for Amblyopsis on account of the great variability of the eye in the adult. While the eyes of the very old have unquestionably degenerated, there is no means of determining what the exact condition of a given eye was at its prime. In the largest individual examined the eye was on one side a mere jumble of scarcely distinguishable cells, the pigment cells and scleral cartilages being the only things that would permit its recognition as an eye. On the other side the degree of development was better. The scleral cartilages are not affected by the degenerative processes and are the only structures that are not so affected. The fact that the eyes are undergoing ontogenic degeneration may be taken, as suggested by Kohl, that these eyes have not yet reached a condition of

equilibrium with their environment or the demands made upon them by use. Furthermore, the result of the ontogenic degeneration is a type of structure below anything found in phylogeny. It is not so much a reduction of the individual parts as it is a wiping out of all parts.

PLAN AND PROCESS OF PHYLETIC DEGENERATION.

Does degeneration follow the reverse order of development, or does it follow new lines, and if so, what determines these lines?

Before discussing this point I should like to call attention to some of the processes of ontogenic development concerned in the development of the eye. There are three processes that are of importance in this connection. 1.—The multiplication of cells. 2.—The arrangement of cells, including all of the processes leading to morphogenesis. Frequently the first process continues after the second one has been in operation. 3.—Lastly, we have the growth and modification of the cells in their respective places to adapt them to the particular functions they are to subserve—histogenesis. Since the ontogenic development of the eye is supposed to follow in general lines its phyletic development, the question resolves itself into whether or not the eye is arrested at a certain stage of its development and whether this causes certain organs to be cut off from development altogether. In this sense the question has been answered in the affirmative by Kohl. Ritter, while unable to come to a definite conclusion, notes the fact that in one individual of Typhlogobius, the lens, which is phyletically a new structure, had disappeared. But this lens had probably been removed as the result of degeneration rather than through the lack of development.

Kohl supposes that in animals placed in a condition where light was shut off more or less some of the developmental processes are retarded. In successive generations earlier and earlier processes in the development of the eye are retarded and finally brought to a standstill; thus every succeeding generation developed the eye less. Total absence of light must finally prevent the entire anlage of the eye, but time, he thinks, has not been long enough to accomplish this in any vertebrate.

The cessation of development does not take place at the same time in all parts of the eye. The less important, those not essential to the perception of light, are disturbed first. The retina and the optic nerve are the last affected; the iris comes next in the series. Because the cornea,

aqueous and vitreous bodies and the lens are not essential for the performance of the function of the eye, these structures cease to develop early. The processes of degeneration follow the same rate. Degeneration is brought about by the falling apart of the elements as the result of the introduction of connective tissue cells that act as wedges. Abnormal degeneration sometimes becomes manifest through the cessation of the reduction of parts (p. 269) that normally decrease in size, so that these parts in the degenerate organ are unusually large.

Kohl's theoretical explanation here given somewhat at length is based on the study of an extensive series of degenerate eyes. He has not been able to test the theory in a series of animals living actually in the condition he supposes for them, and has permitted his erroneous interpretation of the highly degenerate eye of Troglichthys to lead him to the theory of the arresting of the eye in ever earlier stages of ontogeny. The eye of Troglichthys is in an entirely different condition from that supposed by him. The mere checking of the normal morphogenic development has done absolutely nothing to bring about this condition, and it could not have been produced by the checking of development in ever earlier and earlier stages of ontogeny, for there is no stage in normal ontogeny resembling in the remotest degree the eye of Troglichthys. The process of degeneration as seen in the Amblyopsidae is in the first instance one of growing smaller and simpler (not more primitive) in the light, not a cutting off of late stages in the development in the dark. The simplified condition, it is true, appears earlier and earlier in ontogeny till it appears along the entire line of development, even in the earliest stages. The tendency for characters, added or modified at the end of ontogeny, to appear earlier and earlier in the ontogeny is well known and there is no inherent reason why an organ disappearing in the adult should not eventually disappear entirely from ontogeny. The fact that organs which have disappeared in the adult have in many instances not also disappeared in the ontogeny, and remain as so-called rudimentary organs, has received an explanation from Sedgwick. In his re-examination of the biogenetic law he came to the conclusion that "the only functionless ancestral structures, which are present in development, are those which at some time or another have been of use to the organism during its development after they have ceased to be so in the adult."

The length of time in such cases since the disuse of such an organ in the young is much shorter than that since its disuse in the adult.

All organs, functionless in the adult but functional in the early ontogeny, develop in the normal way. Organs no longer functional at any time dwindle all along the line of development. In Typhlogobius, where the eye is functional in the young, it develops in full size in the embryo, and it is not till late in life that degeneration is noticeable. In Amblyopsis, on the other hand, where the eye has not been functional at any period of ontogeny for many generations, where the eye of both young and adult lost their functions on entering the caves and where degeneration begins at an early period and continues till death, the degenerate condition has reached the early stages of the embryo. It is only during the first few hours that the eye gives promise of becoming anything more than it eventually does become. The degree of degeneration of an organ can be measured as readily by the stage in ontogeny when the degeneration becomes noticeable as by the structure in the adult. The greater the degeneration the further back in the ontogeny the degenerate condition becomes apparent, unless, as stated above, the organ is of use at some time in ontogeny. It is evident that an organ in the process of being perfected by selection may be crowded into the early stages of ontogeny by post selection. Evidently the degenerate condition is not crowded back for the same reason. How it is crowded back I am unable to say. A satisfactory explanation of this will also be a satisfactory explanation of the process by which individually acquired characteristics are enabled to appear in the next generation. The facts, which are patent, have been formulated by Hyatt in his law of tachygenesis (Hyatt IX).

Cessation of development takes place only in so far as the number of cell divisions are concerned. The number of cell generations produced being continually smaller, result in an organ as a consequence also smaller. In this sense we have a cessation of development (cell division, not morphogenic development) in ever earlier stages. That there is an actual retardation of development is evident from Amblyopsis and Typhlichthys in which the eye has not reached its final form when the fish are 35 mm. long.

Histogenic development is a prolonged process and ontogenic degeneration is still operative, at least in Amblyopsis.

Degeneration in the individual is not the result of the ingrowth of connective tissue cells as far as I can determine. It is rather a process of starving, of shriveling or resorption of parts.

From the foregoing it is evident that degeneration has not proceeded in the reverse order of development; rather the older normal stages of ontogenic development have been modified into the more recent phyletic stages through which the eye has passed. The adult degenerate eye is not an arrested ontogenic stage of development but a new adaptation, and there is an attempt in ontogeny to reach the degenerate adult condition in the most direct way possible.

The Florida Gopher.

By Wm. B. Fletcher.

If there is any one animal peculiar to the United States and limited in its habits to a very small section, it is the Florida Gopher (Testudo Polyphemus (Daudin) Zerobates Carolinus Ag.), which is found in all the pine barrens and sandy uplands of Florida, and, but rarely, in parts of Alabama and Georgia; never north of the Savannah River.

The word gopher comes from the old French, and means to honeycomb, make numerous holes or burrow, and by the early French settlers was indiscriminately employed to designate all burrowing animals. To nearly all persons living outside of the three States mentioned, the word gopher indicates one of the pouched rodents, rats or squirrels which burrow in the ground and are found from Illinois west to the Pacific coast, and all over the southwestern States. What we call gophers in the North are called salamanders in the South.

Had nature intended to put into any one animal the characteristics of all that is harmless, patient, kind and non-resistent, it is found in the gopher. Possessing greater strength in proportion to its size than any of the vertebrata, yet it never attacks other animals or defends itself from them except by withdrawing its head and legs within the protection of its shell; the horny fore-arms and hands, as it were, placed over the head and face, making a complete armor against the foe, no matter how sharp the teeth or claw may be, or how powerful the jaw of the attacking animal.

The habits of the gopher are those of peace and quietude, except in the rare instances of personal contests with its kind. While it is true

that they are frequently seen in numbers of ten to twenty grazing in the same locality like so many cattle, it is rare to see them close together, and there is seemingly no boud of communication between them, for the gopher is an animal of almost perfect silence and the only approach to vocal sounds is a slight hiss as the head is suddenly drawn in, compressing the lungs and forcing the air quickly through the chink of the glottis; and I have sometimes thought I recognized a faint "mew" like that of a kitten.

The gopher is a most strict vegetarian in his native State, but, under domestication, will learn to drink milk, to eat salads of various kinds, prepared with dressing of eggs, condiments, etc. He heartily abjures all kinds of flesh or insects, and would starve before eating either. He does not seem inclined to social life with his own kind, and invariably lives alone, save for the companionship—either by accident or from choice—of the white and mottled frog, or cricket, that is almost always found in his home, and which is known to the native Floridian as his "familiar." The gopher is thus an example of absolute independence, each dwelling alone in his or her own home; never have I found two in one house, and I know of none having calling acquaintances. The female deposits her eggs, from one to two dozen in number, in the sand at the entrance to her burrow, covers them up to the depth of four inches, and then her domestic duties to her family are ended; she may sit at the doorway and chew her cud when the weather is agreeable, that is, not raining, or too hot from the direct rays of the sun. She may at times cover her deposit with her impenetrable shell to keep them from the opossum or meandering coon; but one thing is certain, when the eggs are hatched by the heat of the May sun, each little gopher—an inch in diameter—goes for itself, finds its own food, makes its own house and is recognized as an independent citizen from the very shell.

When driving through the pine barrens one will sometimes pass a dozen or more of these animals grazing within a few hundred feet of one another. They swing along with heads thrust forward much as if the neck were a cable and the head the motive power, drawing a heavy inverted basin behind. Coming to a tuft of wire grass or other crisp or tender herbage they draw it in by the tongue, cut it off sharply by the triple row of sharp, serrate teeth-like edges of this horny layer of the jaws and swallow it down without mastication. The animal will give little heed to your presence or that of your dog, unless quite near his hole, but will

draw himself within his shell and remain perfectly quiet for from one to five minutes, and then proceed with his journey or browsing, provided you keep still, even though you are within three feet. After feeding he returns to his abode and proceeds to masticate the coarse herbage injested. It is almost comical to see him sitting beside his doorway, his black skinny head thrust out, chewing with great satisfaction the morning's repast. It looks like a caricature of a Florida cracker sitting at the open window of his cabin chewing tobacco; but the gopher doesn't expectorate.

The average size of the full-grown gopher is twelve and one-half inches in longitudinal, and fourteen in transverse measure of the shell, the latter measurement being greater because the enameled shell bends underneath to join the plastron, or breast bone, as we might call it. When the head and legs are drawn in (the animal has no tail) from every aspect there is an arch, compressed, it is true, at the base, and, in the very old, slightly so on the top. It is from this peculiar structure that a gopher in good condition, weighing eight and one-half pounds, can lift two hundred pounds when balanced centrally. I have seen two small gophers, weighing four pounds each, attached to a cart as oxen, draw two lads weighing together one hundred and twenty pounds.

On December the third, last, I took Henry Jordan, a very intelligent native colored man, with me, and went out to get some gophers for dissection. About a mile from Palm Springs, Florida, there is a tract of country, which, eight years ago, contained most valuable orange groves, as the long rows of big dead stumps of orange trees testify. It has been abandoned and the tenantless, decaying villas, with pine and palm trees shooting up through their rotting porches and roofs, and mats of climbing roses and jasmine creeping through the open doors and windows plainly show. In these abandoned fields the gopher has taken up his habitation. On a space of ten acres I counted some fifty gopher holes. The soil is typical of Florida uplands—yellowish brown, or like white salt, is the sand through which some coarse weeds and grasses emerge in tufts. Wherever you see a pile of sand, apparently as much as two flour barrels would hold, slightly spread out in front of an arched doorway, and in that sand see the prints of the dragging shell and toe points going inward to the door, you can safely say that Mr. or Mrs. Gopher will receive callers at home.

The character of the soil or sand in which the gopher loves to delve

much resembles a very light brown sugar, containing so much moisture that you may thrust your cane into it, and withdrawing, leave a hole. We find an entrance to the burrow, which has a hallway perhaps three feet wide and tapering in eighteen inches, with a downward slant to the opening proper; here we come to an arch, one-third of a circle, over a horizontal base which measures fourteen inches; we take a long rod and thrust down the incline and find it goes eight feet at an angle of forty-five degrees and then turns; we lay the rod on top of the ground in the same direction, and dig a foot or two beyond our measure, then down, and strike the hole; from this point the burrow changes direction twice, but always an easy incline downward, the sand gradually becoming more damp as we proceed. After we had made a trench some twelve feet from the entrance large enough to stand and work in, and six feet deep, I asked Henry how far he thought we must go before we got the gopher. "Well, we must jist go on dis road till we git him, if it takes a hundred yards." After digging four feet more and still down, Henry handed up a bleached cockroach, remarking, "We's most' got um; here's one of his 'familiars,' and when we come to de white frog we's got um shore." Sure enough it was so, for the spade went four feet more and we could hear it grate on the shell; at the same time a white frog jumped out. It was a bright-eyed little fellow, with transparent legs and toes. A few black specks about his head made a pretty contrast to his sparkling gold-ringed iris. "Hold on, Henry," I said, "let me pull out that gopher; I fear you will scratch him with the spade." "You can't pull him out wid an ox team," was the reply. "Well, get out of my way and I will show you; he can have no purchase in this wet sand." So in I went, "belly flat," as the boys say when coasting, squeezing myself into the hole until I got my hand on the shell. There were no hind legs to be found, and the wet oval shell was so slippery I had to give it up and be drawn out myself by the legs. "I'll show you how to get 'im widout scratchin' de shell," said Henry, and he proceeded to make a cave under the gopher. Into this he dropped, was scouped out and handed over. We had dug twenty feet, making the gopher's hole twenty-eight feet long and eight deep. In Indiana soil we would have had a half day's job to make this excavation, which, in this soft moist soil, required one hour and a quarter. The pointed, scouped spade used can be pushed into the soft sand without using the foot to propel it.

We dug out four other gophers and found there is no particular rule in the builder's mind as to how far he will tunnel or in what direction. They go into the ground for protection, for comfort and for water. A popular error exists among the natives here that the gopher does not require water because he goes only in dry places and hides from the heavy dews, or even the lightest rains; but I find that he invariably stops his digging when he has reached a sand so moist that he can suck particles of moisture through the sieve-like serrations of his jaws, which, when closed make openings of one fiftieth of an inch. If particles of sand should enter they settle in the deep groove between the serrations of the lower jaw. If you dig a little hollow six inches beyond the lower end of a gopher run you find it soon filled with water oozing up from below.

The gopher makes burrows for the purpose of regulating the temperature to a degree most fitted to his comfort and well being. When he has browsed to his satisfaction and the sun is too hot, he retires to the shade of his cave. If his shell is uncomfortably dry he retires deeper, and if he is thirsty he drinks in the filtered water from his own well. I have taken a gopher out of the ground, stopped up the entrance to his burrow, except the first foot or two, and then watched his puzzled look as he endeavored to enter. He looked curiously about as if taking in certain land marks, then, having got his bearings in mind, would make another dash at the place where his entrance had formerly been. After a half-dozen trials he threw up his head in disgust and marched off. I have put one gopher in another's hole, but it will back out and go away.

At this time I have a gopher in a little chicken coop, which has the sand for its floor. He has been there a week but has made no effort to free himself by digging out. He has buried himself all but about an inch of the rear of his shell, and from there he makes no attempt to go deeper. I have never seen two gopher holes very close together; sometimes one burrow will cross another, but never into it; the nearest being about eighteen inches.

The anatomical peculiarities of the gopher are the head, which, from the rear view, much resembles that of a frog, but is covered with a hard, black, adherent skin or scales; the jaw and tongue quite angular, looking into the mouth it seems a perfect triangle; the tongue has villi much like that of herbiverous animals; it has three well-defined stomachs. The intestine from the third stomach is very large, with muscular arrangement that the herbage injested may be brought up at will, thus the animal is

able to go for weeks using up the stores of provision laid up within the large intestine. A gopher weighing six pounds had a reserve of two and one-half pounds within. I removed one and a half pounds of meat from the shell and legs, leaving the rest of his weight in the skeleton. There are forty-six laminated sections in the shell of the full-grown gopher; these laminae are about one-fortieth of an inch in thickness and readily scale off after the animal dies, leaving under each section a segment of true bone of the same shape and size. The brain of this animal (weighing six pounds) weighs but 40 grains; the spinal cord unusually large. The sympathetic and solar plexus largely developed. The heart is larger than in other testudo of like weight, having two auricles and a large, strong, half-divided ventricle. The lungs are attached to the dorsum of the thorax. The diaphragm is stronger than among the turtles. The ovaries long and broad, containing ten to twenty mature eggs, three-eighths of an inch in diameter, and perfectly spherical. When deposited they have a hard calcareous shell. In my specimen there were three hundred immature ova in the Fallopian tubes and ovaries; the tubes open into a short vaginal sheath an inch from the common outlet. The sex may be distinguished by the males having a concave form of the lower third of the sternum, while in the female it is slightly convex or flat. The upper part of the sternum (plastron) is a solid piece, projecting beyond the shell an inch and a half. The eye is covered with a nictating membrane as in birds.

The general intelligence of the gopher is quite limited. It remembers localities, but I do not think it remembers friends or enemies. I have one that has had the run of my office, house and yard for several months. It has gained in weight and is healthy. She likes a warm, snug corner by the fire when the days are cool; when outdoors she wanders about to certain places where she formerly found good pasturage. She knows where the gate is, and likes to get on the street for a promenade, where she walks on the tips of her strong fore claws; her blunt hind legs and club feet giving her the appearance of a miniature elephant.

The gopher, when turned upon the back, can not return to its natural position, and when one fights another it is to use its projecting sternum as a battering ram, striking his antagonist amidships and throwing him over on his back; then, as the vanquished foe thrusts its head and neck out to regain position, it receives various blows upon the neck from the same source. I have witnessed but one fight of this kind and that was

between two female gophers. The punishment given by the larger one caused the death of the smaller one.

In evidence that there is a necessary transpiration through the under shell or plastron a gopher will die if that part of the body is vanished.

The gopher is eaten and much esteemed as food by the colored people. It is popularly supposed to contain portions of all kinds of meat and fish under its different segments. My experience is that it is more palatable than any other testudo, and it contains but one kind of meat, and that tough.

I must be pardoned for not referring to the literature of my subject. It is because I have found almost nothing, and that brief and incomplete in "Wood's Natural History," and I write this far from libraries and reference books.

Orlando, Florida, December 23, 1899.

Libraries of Microscopical Slides.

By A. J. Bigney.

Since the earliest times it has been the custom of educated people to have libraries. No line of thought has received more attention in the past few years than the biological sciences. Probably the world has received more physical good from such work than from any other source. What the next generation will bring forth can hardly be imagined. Every one who owns a microscope is adding a little to the world's stock of knowledge in biology. Not only does such a worker need books, but he should make another kind of library, a collection of slides. To the teacher in biology this is almost a necessity. To make the slides of greatest use they should be classified in some systematic way. It has been my experience and observation, in small as well as large colleges and universities, that the slides are packed away without any or very little system, and the teacher must depend upon his memory in finding them. This causes very much annoyance and much loss of time. Last fall I classified my slides in a simple way and it has been of so much value to me that I feel

it is important to call the attention of other workers to this, or at least suggest something that will cause them to do the same thing.

The slide box or tray is marked with Roman numerals. The places for the slides are usually marked with the Arabic numbers by the manufacturer of the boxes. On the label of each slide are marked the Roman numeral, which indicates the number of the box in which the slide is to be placed and the Arabic number, which indicates its position in the box.

All the slides are now catalogued on cards or on sheets of paper. In cataloguing, the name of the specimen on each slide should be given and following in the Roman and Arabic numbers on that particular slide. The cards should be arranged alphabetically and kept near the slides. Since the slides are used by the different students, they will have to be replaced, and by this method any one can tell in an instant where they belong. If, for instance, you desire a section of liver, look for same on card. The reference may be XII—24; hence, find box XII, and the slide will be found at "24."

A Method of Registration for Anthropological Purposes.

By Amos W. Butler.

The Board of State Charities has undertaken a registration of the inmates of the various benevolent and correctional institutions of the State. The work began by an enumeration of the inmates of poor asylums, orphans' homes and insane hospitals, some years since, and has been elaborated so as to give the individual and family history of each person. This is now being extended to the prisons, reformatory, reform schools, school for feeble-minded youth, and institution for the education of the deaf. The information to be obtained includes the name, age, color, date of admission, physical and mental condition, together with information concerning education, home influences, religious influences, character of training, whether possessed of a trade, and other facts that are thought will have a bearing upon the individual. Family history includes the names of both parents, the place of their nativity, their pecuniary condition, whether intemperate, criminal, insane, epileptic, feeble-minded or con-

sumptive, whether living together, or dead. It also is intended to obtain whatever collateral information is possible relating to other members of the family.

It is the purpose to extend this investigation, eventually, so that it will include the names of the inmates of all institutions coming under the supervision of the Board of State Charities. The information obtained is being registered upon cards, which are arranged after the manner of a library catalogue, so that everything known about each individual will be readily available in concise form. The purpose of this work is to learn, so far as possible, the causes of dependence and crime and the conditions under which they exist. The value of such statistics, either when one considers the case of the individual or of his descendants, can not be calculated. When fully covering the whole field and extending over a series of years, it will give the State the data from which to arrive at the most important conclusions regarding the treatment of its unfortunates and delinquents.

Aids in Teaching Physical Geography.

By V. F. Marsters.

For a number of years physical geography has barely received recognition in the high schools of this State. From the standpoint of accumulating useful knowledge, as well as achieving mental discipline, it is to be regretted that the subject has received so little attention. It would seem that it has been tolerated or simply permitted to exist, while the sister sciences have been fostered and developed in a manner commensurate with the means at hand. The past few years, however, have witnessed not only a remarkable advancement in geographical science, but also the introduction of new and rationalized methods in teaching the subject. The large accumulation of geographical facts accompanied by an increasing demand for rational explanation or interpretation furnishes the key to the recent interest in this subject.

The importance of geography as an educative science must be conceeded when it is known that the most progressive universities have

SEWANEE MODEL. CHATTANOOGA MODEL.

MARTHA'S VINEYARD.

CAPE COD MODEL.

placed the subject on an equal footing with the other sciences which have for years found a respected place in the college curriculum. That this fact is being recognized beyond the walls of the university must be admitted when we see a number of the larger cities of the country employing specialists to instruct their teaching force and familiarize them with a rational method of teaching. I am informed that the city of Indianapolis has employed a well-trained man for this specific purpose. This is a step taken in the right direction. Moreover, about all the commissioned high schools of the State have placed physical geography on the schedule of studies, although in many cases but a short period is devoted to the subject. These facts point to the conclusion that physical geography has gained a deserved place in the public schools, and, moreover, with due recognition, it is destined to play as important a role as any of its allies as an educative science because of its recognized disciplinary value.

Let us look for a moment at some of the recent methods of teaching the subject. Ten years ago it was all sufficient for the student to describe a geographical element, or simply to accumulate facts. If the student knew all the capes on the Atlantic and Pacific coasts and their locations, nothing more was to be learned about them. The question was not asked why any geographical element should appear here or there, why this or that territorial limit of topographical expression should exist; it was sufficient to be able to know the fact of its existence, location and general features without calling for an explanation. Such knowledge is empirical. The serious student is no longer satisfied with empirical description, but he demands explanatory description. It is in this particular phase that marked advancement has been made. Empirical description is rapidly giving way to rational explanation of geographical phenomena. The absence of an educative discipline in the former, and its necessary inherence in the latter, fully accounts for the recent growth of the so-called new geography. Thus, rational geography demands not only the *collection of facts* by personal observation, but it also calls for an *explanation* of the *observed facts*; such a process must employ comparison and deduction. Moreover, the conclusions reached or the method of explanation derived by comparison and deduction must explain not only all the facts at hand, but they must also account for many other related facts yet to be collected. It is only by the employment of these broad and fundamental principles that the accumulation of useful knowledge and, above all, a valuable mental discipline can be attained.

There are many aids towards this end. It is, however, only within recent years that much of this material so useful to the geologist, as well as to the geographer, has come within the reach of the secondary schools. The apparatus, which should be found to some extent at least in all schools and colleges purporting to teach geography, may be described under the following headings:

1. Photographs and lantern slides.
2. Maps.
3. Models.

1. Photographs.—The collections of photographs, made by the usual dealers, furnish very little material that has any special geographical significance. Such collections are usually made with reference to depicting some artistic expression in a landscape, and invariably fail to bring out such topographic outlines as would be of significance to the student of geography. A fairly useful selection can be made from a collection made by various members of the Geological Society of America, and placed in the hands of a committee for classification and distribution. Further information may be obtained by applying to G. P. Merrill, Washington, D. C., or to Prof. F. L Fairchild, Rochester, N. Y.

Lantern slides are even more useful than photographs because they present a more vivid picture, and details more easily discerned. Moreover, the relation of parts are more clearly brought out because of the enlargement; in fact, it is the next best to seeing the actual thing illustrated. In the use of the lantern, however, care should be taken not to introduce this method of illustration as simply a species of entertainment, but rather as an essential part of the course to be absorbed by the student as well as text or lecture.

What has been said of the insufficiency of the dealers' photograph collections is equally true of their lantern-slide collections. An examination of the stock of a number of dealers furnished but little useful material. This long-felt want has in part been supplied by Prof. W. M. Davis, who has made a very excellent collection of about one hundred and fifty slides, illustrating the prominent and essential features of the forms of the land, rivers, lakes, glaciers, shorelines, waves, etc. The entire collection may be obtained from E. E. Howells, Washington, D. C.

In the interest of Indiana geography, it is proposed to make a collec-

tion of photographs and lantern slides during the coming year, which may illustrate the most common and prominent topographic features of the State. It would, of course, be desirable to have both series in the schools, but when the purchase of a lantern is not possible, photographs, of course, may be substituted. It is hoped that such a collection of laboratory material may create and stimulate further interest in the subject and help to place it on an equal footing with the other observational sciences observed in the school system.

Maps.—There are a number of sources from which many selections of useful illustrations of topographic types may be obtained. The United States Geological Survey has prepared a large number of topographical and geological sheets covering portions of the United States. It is to be regretted that this national organization has not published a single sheet covering any portion of the State of Indiana. A part of this neglected work is being done by the Geological Department of Indiana University. In addition to the series of sheets mentioned above, the National Survey has lately prepared a large number of folios, forming a part of the "Geologic Atlas of the United States." These have been made to serve educational purposes in particular, but strange as it may seem, a large number of the best equipped high schools of the State have failed to make use of the opportunities offered. The folios contain a topographic sheet, a second showing the areal geology, a third illustrating the geology in cross section, and sometimes a fourth devoted to the economic geology. Each folio is accompanied with an explanatory text.

From the United States Coast and Geodetic Survey may be obtained a series of maps giving the minutest details of shore-line topography. For a list of the maps address this department at Washington, D. C.

It is gratifying to learn that in a few of the high schools of this State the daily weather maps are being used with a considerable degree of success. These may be obtained by addressing the local forecast official, C. F. R. Wappenhans, Majestic Building, Indianapolis.

Another source for information of meteorological interest is the United States Hydrographic Department, which issues each month a series of pilot charts of the North Atlantic and North Pacific oceans. On these charts are shown the storm tracks, the date of their occurrence and the direction of their course (from which can be determined their rate of movement), calms and prevailing winds, derelicts and wrecks, icebergs and field ice, regions of frequent fog, etc.

The most available source for information on all these publications, and offering assistance in the selection of types from each group, is a little manual entitled "The Use of Governmental Maps in Schools," by Messrs. Davis, King & Collie, and published by Henry Holt & Company, New York.

For information concerning foreign maps, the teacher is advised to consult an article by Prof. W. M. Davis on "Large Scale Maps for Geographic Illustrations," published in the Journal of Geology. A reprint of this article may possibly be obtained by addressing Prof. T. C. Chamberlain, Chicago University.

Models.—One of the most novel and still most effective means in the teaching of geography as well as geology, is supplied by models illustrating the topographic form and the rock structure upon which the topography is made.

Models are of two kinds: One may represent the actual topography of a surveyed section of country and the other may be an idealized land form, depicting the essential and expectable features. The latter may be called "types of land form." Of all the materials mentioned, as forming equipment for a geographical laboratory, models may be regarded as of special value. It is indeed unfortunate that the cost of models in general is so excessive that a large number of the secondary schools may not be able to purchase the larger and most expensive illustrations of land forms, but still there are many that come within the reach of schools with but meagre appropriations.

During the past year the Department of Geology and Geography, Indiana University, has given a course in physiographic geology. Practice in the construction of relief maps may be taken as part of the laboratory work required in the course. It is of course evident that a knowledge of the various methods of making relief maps is of great advantage to the teacher who may be called upon to accumulate material for a geographical laboratory. As a result of this course, the following relief maps have been constructed, the data having been obtained from the topographic and the geologic atlas sheets, published by the United States Geological Survey:

Chattanooga and Sewanee Sheets, Tennessee, horizontal scale, 1″=1 mile; vertical scale, 1″=1,600 feet.

Harper's Ferry Sheet, Baltimore, Md., horizontal scale, 1″=1 mile; vertical scale, 1″=1,600 feet.

Martha's Vineyard Sheet, horizontal scale, 1″=1 mile; vertical scale, 1″=400 feet.

Cape Cod, horizontal scale, 1″=1.5 miles; vertical scale, 1″=600 feet.

Amsterdam Sheet,* New York, horizontal scale, 1″=1 mile; vertical scale, 1″=1,000 feet.

The following models are in process of construction: Boston Harbor Sheet, Mass., and the Sun Prairie Sheet, Wisconsin. These models will show some very excellent types of glacial topography. The completed series of models illustrate some of the most common and conspicuous types of topography and geological structure. It is, indeed, just the kind of material that should be found in the laboratories of the secondary schools. In order that some assistance may be given in this direction, the geological department has preserved the negatives of the models mentioned. From these any number of positives may be prepared; and it is proposed to supply copies of one or more of these to any high school desiring to establish a geographical laboratory. Copies will be sold at the cost of construction, so that the school with but meagre appropriations can at least make a beginning by adding one model each year to the laboratory equipment. It is hoped that the high schools of the State will not be slow in taking advantage of the opportunity here offered. Effective work in geography can not be done without a laboratory; and of the kinds of available material mentioned, maps and models should form a prominent part of the equipment. The writer will gladly correspond with any one desiring further information.

Geological Laboratory, Indiana University.

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*Constructed by E. R. Cumings, Instructor in the Department of Geology, Indiana University.

Some Preliminary Notes on the Hygienic Value of Various Street Pavements as Determined by Bacteriological Analyses.

By Severance Burrage and D. B. Luten.

In many of our large cities, and small ones, too, the question of pavement is a very important one. The government looks largely upon the question of economy, the life of the particular pavement being perhaps the most important factor in assisting them to a decision for or against it. Some pavement companies in pushing their own work, will claim that their pavement is more sanitary than this or that one. Have they any data, any facts that will permit them to make such statements? It was partly for the purpose of settling this question that the foregoing experiments were undertaken.

In working on this subject, it has been found that the sanitary or hygienic value of a pavement depends almost entirely on its power to collect, retain or give up dust, although there are other factors, such as reflection of heat, etc., that must be considered. But this dust leads to a discussion of the point as to whether a strictly sanitary pavement is one that will remain moist the longest time, thus holding on to the dust, and at the same time, perhaps, permitting the multiplication of bacteria; or whether the sanitary pavement is the one that dries the quickest, and with the assistance of traffic and the winds, scatters the dried dust broadcast.

Street dust is always laden with bacteria, and it was thought that possibly some bacteriological analyses under different conditions might assist in the solution of this problem. It is not necessary to state that aside from the bacterial contents of dust, hygienically speaking, it in itself is an irritating factor to the mucous membrane of the nose and throat, as well as to the delicate membranes of the eye. And thus, without taking the bacteria into account at all, the pavement permitting the least dust would be regarded as most sanitary. But the bacteria usually occur in proportion to the amount of other dust, so the measure for one will serve fairly well as an indicator for the amount of inorganic dust. The experiments herein reported were undertaken on the Lafayette, Indiana, pavements, including macadam, brick, wood block (not creosoted), and sheet asphalt.

There is almost no reliable literature on the subject, and what little there is seems to universally condemn the uncreosoted wood block pavement.

From Byrnes Highway Construction, 1893, Dr. O. W. Wight, Health Officer of Detroit, in a report to city council, says: "On sanitary grounds, therefore, I must earnestly protest against the use of wooden block pavements. Such blocks, laid endwise, not only absorb water which dissolves out the albuminous matter that acts as a putrefaction leaven, but also absorbs an infusion of horse manure, and a great quantity of horse urine dropped in the streets. The lower ends, resting on boards, clay or sand, soon become covered with an abundant fungoid growth, thoroughly saturated with albuminous extract and the excreta of animals in a liquid putrescible form. These wooden pavements undergo a decomposition in the warm season and add to the unwholesomeness of the city. The street in fact might as well be covered a foot deep with rotting barnyard manure so far as unwholesomeness is concerned. Moreover, the interstices between the blocks and the perforations of decay allow the foul liquids of the surface to flow through, supersaturating the earth beneath and constantly adding to the putrefying mass."

M. Foussagrivs, professor of hygiene, at Montpelier, France, objects to wooden pavements because they "consist of a porous substance capable of absorbing organic matter, and by its own decomposition giving rise to noxious miasma which, proceeding from so large a surface, can not be regarded as insignificant. I am convinced that a city with a damp climate, paved entirely with wood, would become a city of marsh fever."

An article by Amat in the Bull. Gen. de Therapeut, is of some interest in this connection. He compares the advantages and disadvantages of wood pavement with those of granite blocks and asphalt. In regard to cleanliness he places then in the order of merit—asphalt, granite, wood. In regard to quiet—wood asphalt, granite. In regard to cheapness—granite, wood, asphalt. Durability—granite, asphalt, wood. Ease of repair—asphalt, wood, granite, and safety—wood, asphalt, granite.

Miguel tested bacteriologically some ten-year-old wood pavements, and found from a million to a million and a half germs in a gram of sawdust from the surface, and from five hundred to four thousand in a gram of the sawdust taken two inches below the surface. These same experiments were repeated by Rolst and Nicoles, giving the same relative results, but the numbers of bacteria being twenty times as large.

Professor Brown, of Yale College, says that "even in the free air and full sunlight, along with the putrescence, a white fungous growth begins on the surface of the wood, which rapidly becomes slimy. This forms much more rapidly on the ends of the grain of the wood than on the radial or tangential sides. The fungous growth goes on, modified of course by the temperature and the degrees of concentration and it continues for an unknown period, or until decay has become complete. Heartwood and sapwood act alike in this matter; the difference is one of degree rather than character."

The Legislature of New South Wales (Australia) appointed a board to "inquire into the alleged deleterious effects of wood pavements upon the public health. The board examined specimens of wood pavements as laid in the city of Sidney, taking up blocks at different points. In all cases the concrete bed underneath was moist; in three cases a large amount of slimy mud was found, giving off an ammoniacal odor. The blocks were chemically examined to determine whether they had absorbed organic matter, with the result that some were found impregnated with filth to the very center, while others were comparatively free from it. The board comes to the conclusion that wood is a material which can not safely be used for paving unless it can be rendered absolutely impermeable to moisture. * * * So far as the careful researches of the board go, the porous, absorbent and destructible nature of wood must, in its opinion, be declared to be irremediable by any process at present known; nor were any such processes discovered, would it be effectual unless it were supplemented by another which should prevent fraying of the fibers. Still less can the defects of wood be considered of less consequence than the defects of other kinds of materials. * * * Your board therefore recommends that the paving of the streets of this city with wood should be discontinued, and desires to add that this recommendation is extended to apply not to the particular mode of construction here adopted alone, but to the material itself and to every known method of construction."

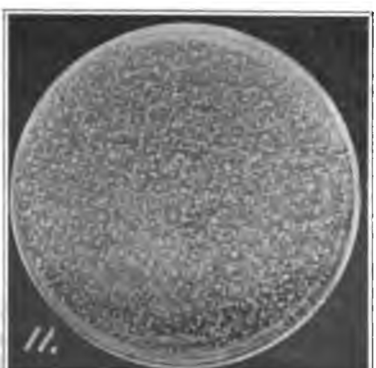
On the other hand, a comparison of the death rate in cities using wood pavements with that in cities where little or no wood is employed seems to show that wood pavements do not cause an increase in the death rate, i. e.:

Macadam.

Sheet Asphalt.

Wood Block.

Brick.



Sheet Asphalt.

Brick.

City.	*Death-rate.*	*Percentage of Wooden Pavements.*
New York	25.19	0
Boston	23.00	0
Philadelphia	19.74	0
Nashville	23.70	0
Atlanta	19.87	0
Milwaukee	16.90	48
Chicago	17.48	80
Detroit	14.70	91
Duluth	99.17	95

If there were not so many other conditions this might be convincing in favor of wood block. All these data were collected about 1890.

Fig. 1.

The two latest books on pavements (1893 and 1894) contain nothing better. As far as technical journals are concerned, the matter seems to be considered satisfactorily settled by such arguments as the preceding; no further investigations along these lines seem to have been made.

METHODS OF ANALYZING AIR OF PAVEMENTS FOR BACTERIA.

The bacteriological examinations were carried on by means of using the agar plate exposure, four-inch Pasteur dishes being used. These agar plates were exposed (always in duplicates) on an ordinary surveyor's tripod, as shown in Fig. 1. This made the exposure about five feet above the pavement. Half way between the exposed plates and the pavement hung the anemometer, which had to be used to determine differences in wind velocities from minute to minute. These plates were always exposed for exactly ten minutes, and careful notice taken of the amount of traffic, direction of wind, and anything that would affect the amount of floating dust. Great care was taken to see that the wind was blowing as nearly parallel to the street as possible, so that the analysis would surely be of the street dust, and not of the dust from the adjoining lots.

One set of exposures was made between 12 and 2 o'clock at night when the life on the streets would be at a minimum. The results of this set of plates were as follows, the numbers indicating the number of bacterial colonies on each agar plate that had had an exposure of ten minutes:

Wood block (uncreosoted), Plate No. 3	50
Brick, Plate No. 5	16
Sheet asphalt, Plate No. 2	14½
Macadam, Plate No. 1	9½

The numbers indicate the average number of bacterial colonies on the two plates that were exposed side by side over each pavement.

Another interesting set of exposures was made at a time when the macadam street was muddy, the brick pavement was fairly dry, except for moisture in the interstices, and the sheet asphalt was dry. A drizzling rain had occurred about twenty-four hours previous to the exposure. Results as follows:

Sheet asphalt, Plate No. 11	2850
Macadam	147
Brick, Plate No. 13	99

In this exposure it was evident that the sheet asphalt pavement had become quite dry and the dust was stirred up to a very considerable de-

gree by the passing traffic, fifty-three carriages, two bicycles and one horseback going by during the ten minutes' exposure. The wind was very light.

Another exposure was made when everything was dry, and after the wind had been strong and gusty for some hours, with the following results:

Macadam	958
Brick	463
Wood block (uncreosoted)	304
Sheet asphalt	180

Here the sheet asphalt had apparently been wind-swept, and was clean and dry.

The averages of all exposures, excluding the midnight one, were as follows:

Macadam	1386
Sheet asphalt	1084
Brick	960
Wood (uncreosoted)	361

Therefore, if the amount of dust floating over any given pavement is a measure of the sanitary value, these pavements in question will take the following rank: wood, brick, sheet asphalt and macadam. The above averages include exposures under all kinds of varying conditions.

While we do not feel that we can conclude anything very definite from these experiments, they seem to point to possible conclusions of value if pursued to the proper extent. Previous opinions commending or condemning any pavement from the sanitary standpoint lack scientific foundation, and therefore are not to be seriously considered. In the experiments herein reported there are a number of factors that need to be more carefully determined, such as, that the bacteria that are caught on the agar plates actually come from the pavement and not from the surrounding lots and buildings; and furthermore, that these bacteria are of a pathogenic nature or not. These uncertain features are receiving careful attention in our future experiments, and it is hoped that in their study will be found the key to the solution of these pavement problems.

Insects as Factors in the Spread of Bacterial Diseases.

By Severance Burrage.

From the earliest times theories have been advanced relative to the spread of disease by insects. Just what part the insect played of course was unknown, and naturally must have remained unknown until the discovery of bacteria and their relations to diseases firmly established. But since the germ theory has been established the subject of insects and disease has received much attention, although not all that it may have deserved. The bibliography on the subject, collected by Dr. George H. F. Nuttall, numbers nearly four hundred papers and articles, many of them representing exhaustive experimental work, and others are of general interest, and of practical value.

Books on hygiene and sanitary science, even the latest editions, do not mention insects as disease-spreading factors, yet they go into detailed discussions of many less important subjects. Undoubtedly many epidemics of contagious and infectious diseases have been caused directly or indirectly by insects, and then laid at the door of the water supply, infected food, or bad drainage. While water or milk may have been the immediate means of spreading the disease among large numbers of individuals, *one* insect may have caused the infection of the water or the milk.

As a disease carrier; we must regard an insect in one of two classes. He may be either the simple carrier of the bacteria, transporting the germs of disease on or in his body from an infected person to some healthy person's environment, the bacteria being wiped off from the insect's body or deposited in his excreta on the food or clothing of the susceptible healthy person; or the insect may be an intermediate host, in which the parasite or germ undergoes a part of its life cycle, and then the germ is transmitted to the healthy individual through the sting of the insect, the insect's fang acting as the inoculating needle.

In the latter class the mosquito and cattle tick are the best known, the mosquito carrying the malarial plasmodium, and the tick the organism of Texan cattle fever. Notwithstanding the importance of these diseases from the hygienic standpoint, they do not come under the head of bacterial diseases, as they are caused by animal parasites. It would, perhaps, be well to mention, however, in passing, that the theory connecting mosqui-

toes and malaria has been established beyond a doubt. More research work has been done in this connection than along any other line of the subject.

While not overlooking the importance of the mosquito theory, this paper must deal more with the strictly bacterial diseases.

HISTORICAL.

We are indebted to Dr. G. H. F. Nuttall, M. D., Ph. D., of Johns Hopkins Hospital, for collecting the facts along these lines and publishing them in one pamphlet.[1] There is much literature quoted on anthrax and its connection with various insects, particularly the fly. There are but few positive cases recorded, although scientists do not hesitate to say that insects probably do play an important part. Experimental work was carried on with anthrax and biting flies in 1869 and 1870, independently, by Rainbert and Davaine.

The bodies and the proboscides of the flies, such as tabanus, haematopota and stomoxys, were infected with anthrax material, and after a definite time, such as two, twelve or twenty-four hours, parts of these infected animals were inoculated into healthy animals. In nearly all cases of this kind the animals died of anthrax.

Railliet sums up these and other experiments with anthrax and biting flies by saying that it is conceivable that the proboscides of stomoxys and similar flies may inoculate septic organisms, having previously become contaminated on cadavers or diseased animals; "nevertheless no direct proof has been given as yet in favor of this view." Nuttall goes on to say that it seems "perfectly absurd that any value should have been attached to such experiments. When the insect sucks blood it injects uninfected saliva, and sucks up the bacteria that may adhere to its proboscis; and while it is conceivable that infection may occur, it is more probable, when we consider the process, that infection is the exception and not the rule."

Some forms of beetles are supposed to have been active agents in spreading anthrax. Proust and Hien made examinations of skins that had been supposed to cause anthrax in persons handling them. Living dermestes vulpines and various larvae were found. All the living insects were found to have spores of anthrax on their bodies and in their excreta.

Nuttall carried on a valuable series of experiments with the bed bug

[1] Johns Hopkins Hospital Reports, Vol. VIII, Nos. 1 and 2, Baltimore, Md.

and flea and anthrax, but all his experiments gave negative results, and he concludes that "infection through the bite of a bed bug either does not occur or is exceptional; and further, that infection might occur if this bug were crushed, and the part scratched, is self-evident." And in regard to fleas, the anthrax bacilli die off rapidly in them, and the conclusion appears justified that they can not play much of a rôle, if any, in the spread of this disease.

The plague is supposed to be spread in some measure by means of flies and other insects. Nuttall's conclusions, as far as the biting insects are concerned, are the same as under anthrax, namely, that infection through their bites is exceptional and not the rule, but, "on the other hand, it is quite possible that a person crushing an infected bug, and scratching the spot where the insect has bitten, may thus inoculate himself with the plague bacillus. This, however, would not take place if a sufficient interval of time had elapsed after the bug had sucked blood containing the bacilli."

But Nuttall's experiments with flies infected with the plague bacilli, by which he determined that infected flies could live for several days, point to the possibility as he rightly concludes, that they play no inconsiderable role in the spread of the plague, for they have plenty of opportunities to gain access to food into which they might fall and die, or on which, in again feeding, they would deposit their excreta laden with plague bacilli.

Nuttall was satisfied that the flies themselves could die of the plague. A few experiments are recorded with hog erysipelas, mouse septicaemia, recurrent fever, chicken cholera, and yellow fever, which result in very positive conclusions. Experimental and other evidence points conclusively, however, that Asiatic cholera is disseminated by flies. Tuberculosis and leprosy are undoubtedly spread in this way.

Particular attention was called, during the recent war with Spain, to the spread of typhoid fever through our camps. In fact, it was well demonstrated that the fly played a most important part in the spread of disease throughout the camps, making due allowance for the other factors, such as poor food and bad water. All the conditions about the camps seemed to favor the fly in his dirty work. Flies are attracted alike to food material and to filth. Fecal matters, fresh from the bowels of typhoid patients, and oftentimes without even an apology for disinfection, lay ex-

posed in open trenches, and in sultry weather millions upon millions of flies swarmed on and about this material.

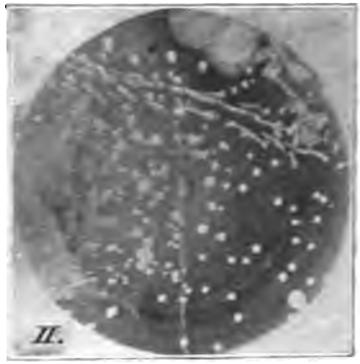
Short distances away from these trenches were the cooking and dining tents, and between these two sources of fly attraction the insects were continually passing. Thus it was made only too easy for the flies to transfer infectious material from the trenches to the food; and as much of the food is not cooked at all, there is no chance for the germs to be killed.

To show the condition of affairs in the camps, as described by an eye witness, I will quote from a letter of Dr. I. W. Heysinger, of Philadelphia, to one of the medical journals: "In the hospitals, the vessels used by the patients beside their beds, were black with them (flies), and they only disappeared when the dinners were brought along, and the attendants went back to the cook house to chase off the invading inhabitants there, and bring up milk to complete the menu. The open sinks are also black with these buzzing scavengers, which rise in clouds when the surface is disturbed, and their feet loaded with fecal debris rise to seek new pastures at breakfast, dinner and supper and all through the day, intermittently around the cook house.

"Into these sinks go the discharges of the typhoid patients, and pathogenic bacteria that can not make an effective culture there on a most majestic scale are 'simply not in it.'

"Can anyone wonder that a single case of typhoid will thus infect a a whole camp and increase the virulence of a mild case to the point of a necessarily mortal result? Ingenuity could not devise any plan so simple, so efficacious and so widespread as this for scattering a pestilence. Every fly leg is good for a large number of almost any required sort of pathogenic bacilli, and some flies are nearly all legs, and the rest snout and wings, which also play their part with regularity and despatch." Dr. M. A. Veeder, of Lyons, N. Y., describes the conditions around a private house. He says: "Even in a private house, not at all uncleanly, I have seen typhoid dejections emptied from a commode, and the latter thoughtlessly left standing, without disinfection, within a few feet of a pitcher of milk just left at the door, both the commode and the pitcher attracting the flies, which swarmed about and went from one to the other. Is it strange that there were numerous cases of the disease in that house, and in the house next to it? I have seen a shallow, old-fashioned water-closet fairly buzzing with flies on a hot day, and all around it open win-

I.



II.

III.

IV.

V.

dows and doors leading into kitchens, pantries and dining rooms. A single case of typhoid would start a severe local epidemic under such conditions."

Summer work in a bacteriological laboratory would convince anyone of the flies' liking for pathologic material of any kind. They are sure to light near and crawl over slides being prepared for stains, which makes it necessary to cover everything with bell-jars to prevent laboratory infection. Moreover, flies are always more attracted toward diseased persons than toward the healthy ones.

The whole subject is of great interest to the sanitarian, because it opens up a comparatively new field in preventive medicine. It applies to the home as well as to the community in regard to general cleanliness and methods of garbage disposal.

STRUCTURE OF HOUSE FLY.

Any one who has examined the fly's foot under the miscroscope can not fail to see how perfectly it is constructed for the retention of dirt and filth. The fine hairs and the suctorial discs afford magnificent opportunities for infectious material to be lodged in and thus transported from one spot to another. In fact, in making a microscopical examination of several flies' feet for the purpose of making a photograph, it was next to impossible to find one that did not have considerable dirt attached to it.

The proboscis of the fly also affords an excellent resting place for dirt of any kind, and the wings and body also serve to retain material. Thus the fly seems to be made for the purpose of carrying small quantities of dirt around with him all the time, a circumstance that is quite alarming if we could follow in the wake of the fly in his daily and hourly travels, instances of which have been cited above.

LABORATORY WORK.

While laboratory experiments are not always satisfactory in a subject of this kind, yet I take the liberty of describing here some that were undertaken in the Purdue laboratories during the past year. While the experiments, in part at least, have been done in other laboratories, the results obtained here were very satisfactory, and the plates were so well marked that I deem them well worth the attention of the Academy.

Experiment No. 1. Typhoid Fever and Fly.—The fly was placed under the bell-jar with filter paper saturated with fresh boullion culture of B. typhi abdom., twenty-four hours old. The fly was closely watched, and after he had been observed to walk over the filter paper several times, the bell-jar was carefully moved from the filter paper. After twenty minutes had passed, a Petri plate containing a thin film of sterile agar was placed under the jar, and the fly again watched. He did not seem to be attracted to the agar, and after waiting perhaps half an hour, it was decided to force the fly to walk over the agar film. So he was carefully caught between the agar film and the Petri dish cover, and he then walked over the agar beautifully. The agar plate was incubated for twenty-four hours and the result was very significant. It is shown on plate No. 1, on which the clearly defined fly path, marked by bacteria colonies, is clearly shown. A further examination determined the presence in these colonies of the typhoid bacilli.

Experiment No. 2.—A similar experiment with some filter paper, saturated with typhoid fever, using another fly, somewhat less time elapsing between his inoculation, and being made to walk over the agar. This fly did not enjoy walking on the agar and jumped around over the plate considerably, as shown by the large number of colonies; plate II. Once or twice he made a fairly straight track, however, as may be seen. These colonies were also proved to contain typhoid fever.

Experiment No. 3. Prodigiosus.—Large fly. After one-half hour walked over gelatine; too lively to make tracks; infected whole plate; plate III.

Experiment No. 4. Prodigiosus.—Fly's wings removed, and then he was allowed to walk over infected paper and agar plate; plate IV.

Experiment No. 5. Prodigiosus.—After eighteen hours fly, that had been infected with prodigiosus, was allowed to walk over plate; plate V.

CONCLUSIONS.

It is evident that the fly can become infected with bacterial filth and hold on to it for sufficient time to inoculate food materials or other materials surrounding human lives. They must always be regarded as a menace to health as long as they have access to filth in the neighborhood

of human dwellings, be they temporary or permanent. All evidence points to the strong need of disinfecting or destroying all the wastes from ourselves and other animals, destroying all excreta in which the flies deposit their eggs, and to do all to eliminate this factor in the spread of infectious and contagious diseases that heretofore has received so little attention.

House Boats for Biological Work.

By Ulysses O. Cox.

House boats for pleasure are not at all uncommon on the Mississippi River, but one built and equipped for scientific purposes was, until the past summer, entirely unknown on that stream, and, I am told, on most streams in this section of the country. Last March the writer was called to Minneapolis by the director of the State Zoological Survey, Professor Nachtrieb, and asked to suggest plans for further study of the fishes of the State. Among these suggestions was the one that a house boat, or rather, in this case, a floating laboratory, be built at Mankato to float down the Minnesota and Mississippi rivers, at least as far as the State line.

There were a number of things to be taken into consideration. It had been several years since the Minnesota River had been navigated by any craft larger than a row boat, and just how large the floating laboratory could be made and still float and be manageable was a question. There were numerous bridges to pass, many sand and gravel bars to interfere and hundreds of snags to be avoided. It was finally decided to build the barge portion of the boat twelve feet wide, twenty-two feet long, two feet deep and with a flat bottom. It was estimated that a boat so built would draw, when empty, no more than five or six inches of water, which estimate proved later to be correct. On top of the barge was built a cabin twelve feet wide, fourteen feet long and six and one-half feet high. The roof of the cabin was covered with boards and then with canvas. At each end of the cabin a door opened out on the platform, which was as long as the width of the boat, and four feet wide. On each side of the

cabin there were two long, movable windows. In one corner of the cabin there was a well equipped dark room for photographic work. Along one side of the room was a laboratory table fitted with drawers and shelves, and in another part were numerous shelves for specimen jars and dishes. A common cooking stove adorned one corner of the room, and in the floor were two large galvanized-iron tanks in which eatables were stored. Besides a complete cooking outfit, cots and bedding, we had various kinds of seines, gill nets, hooks and lines, microscopes, dissecting tools, injecting apparatus, and all other things needed for preserving any material that we might find. Besides a large number of jars and bottles, two large galvanized-iron tanks served for storing preserved material. Formalin was used altogether for preserving museum and anatomical material, and it worked exceedingly well, except when left in the sun. Under the latter conditions, the formalin seemed to decompose and the material would spoil.

We guided our boat, which we named "Megalops," by means of two large oars that worked in oar locks placed on each end of the boat, and we found no difficulty whatever in directing the boat just where we wished, except when the wind was blowing. At such times it was frequently necessary to anchor until the wind ceased. Our speed was seldom rapid, but it was usually very satisfactory. We would move a mile or so and then probably stop a day or two to investigate the ground, and would remain at one place as long as the collecting was profitable. During the four months we were out we traveled from Mankato on the Minnesota River to Red Wing on the Mississippi, and did not meet with a single accident of any consequence. It will be remembered, also, that much of this distance is frequented by steamboats, rafts and floating logs.

At times there were as many as six persons in the party, but usually only five. During the four months that the Megalops was in commission, the following persons were on her for work: Prof. H. F. Nachtrieb, of the State University of Minnesota, and Chief of the Zoological Survey: Dr. D. T. McDougal, of the Bronx Park Botanical Gardens, New York City; Dr. W. S. Nickerson, of the Minnesota State University Medical School; W. S. Kienholtz, J. E. Guthrie, and Charles Zeleny, students of the University; George Hinton, the "boy" and "cookee," and the writer, who was dubbed the "captain."

In every way the trip was a success. We discovered a number of

what may prove to be new species of fishes, certainly new to Minnesota; collected a great many insects, some of them new, and a number of reptiles. Besides these, extensive data were secured concerning a number of fishes, valuable histological and embryological material was preserved, and a number of anatomical preparations were made. There is no better way, it seems to me, to study the fauna and flora of a river than by such a floating laboratory, and I wish to strongly commend the plan to any persons who are considering plans for such study.

The Megalops now lies anchored at Red Wing Minnesota, on the Mississippi River, and it will likely continue on down the river the coming season, after which it may become a part of the equipment of a permanent biological laboratory on the Mississippi, which it is hoped will soon be established by the University of Minnesota.

Tests on Some Ball and Roller Bearings.

By M. J. Golden.

These tests were made to determine the comparative friction of ball and roller bearings when used for shafts under ordinary shop conditions, so the simplest forms obtainable were used, and they were tested at such speeds as usually occur in shop practice. When used in shop practice two or more of these bearings are placed side by side and in this way an ordinary hanger or other such piece of apparatus is built up. In the test the unit of the maker was taken for the size tested and no effort was made to establish any relation as to comparative sizes.

The bearings selected were for shafts one and fifteen-sixteenths inches in diameter, and as the shaft turns in direct contact with the rollers, the spindle used was a piece of regulation, cold-rolled, shop shafting of this size. This piece of shafting broke down before the bearings were affected. The ball bearings, of which three were used, were of the form shown in fig 1. In this figure the full form for a shaft is shown. In the test the bearing at one end was used. This consists of an inner ring of case-hardened steel fitted closely to the shaft and having a V groove cut around the outside. The balls travel between this groove and a corresponding

outer groove. The sides of the outer groove are separate rings that are held in a frame, one fixed and the other adjustable by means of a screw thread cut on the inside of the frame, and a corresponding one cut on the outside of the ring. Adjustment of the bearing to the balls is gotten by means of this ring. This gives a four-point bearing in which the balls travel in planes perpendicular to the axis of the shaft. The balls were .5 inch in diameter.

The roller bearings used were of the form shown in fig. 2, in which, however, is shown a bearing having four sets. In the test, only one set

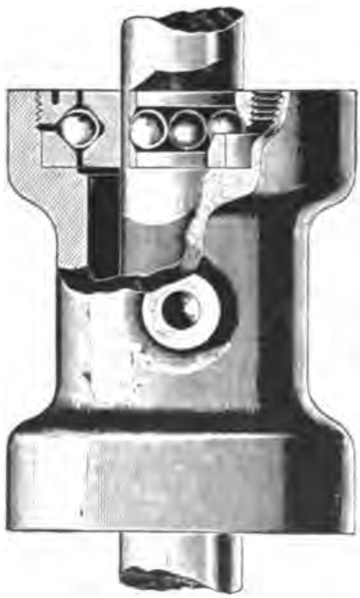
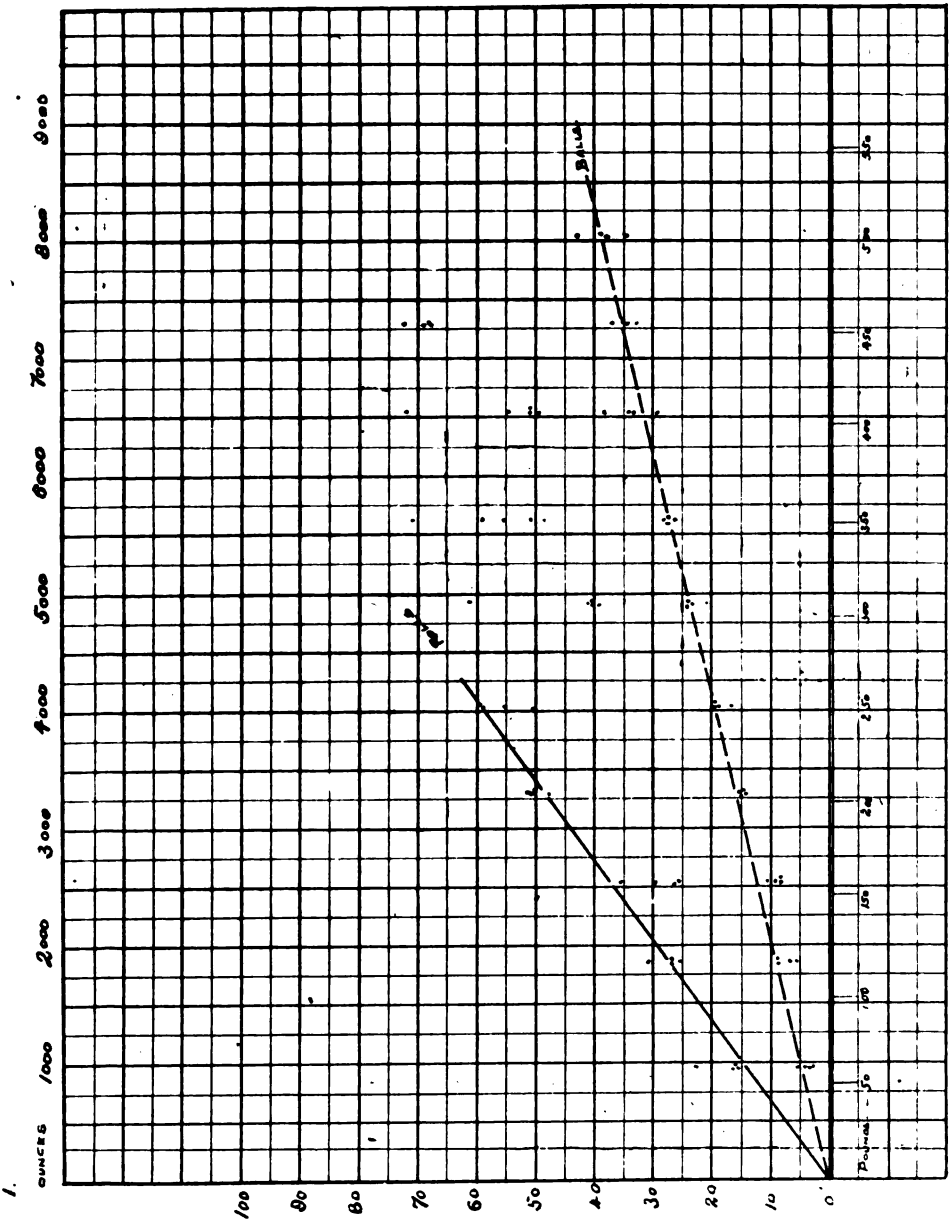


Fig. 1.

Fig. 2.

was used, as this was the unit in building the bearing. This consists of a cage holding fourteen small rolls, of hardened steel, each .315 inch in diameter and .625 inch long. These are separated from one another in the cage by brass bars. During the operation of the bearing the only friction between the cage and rolls ought to be that induced by the weight of the cage. It was found that the heavier loads caused the cage to become badly worn where there was contact between the ends of the rolls and the cage. The cage and rolls are held in a cylinder of steel that is carefully bored,


1.
OUNCES
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40
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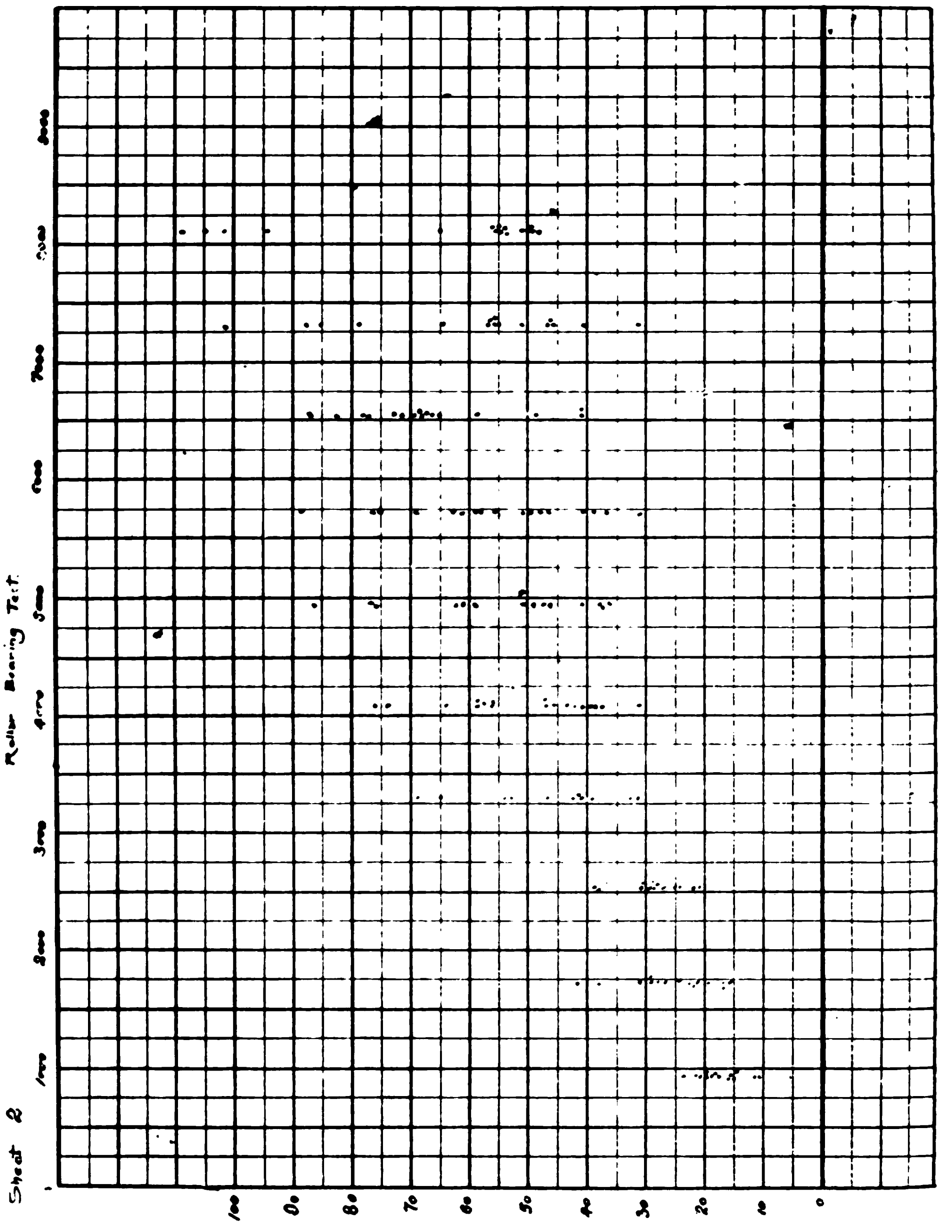
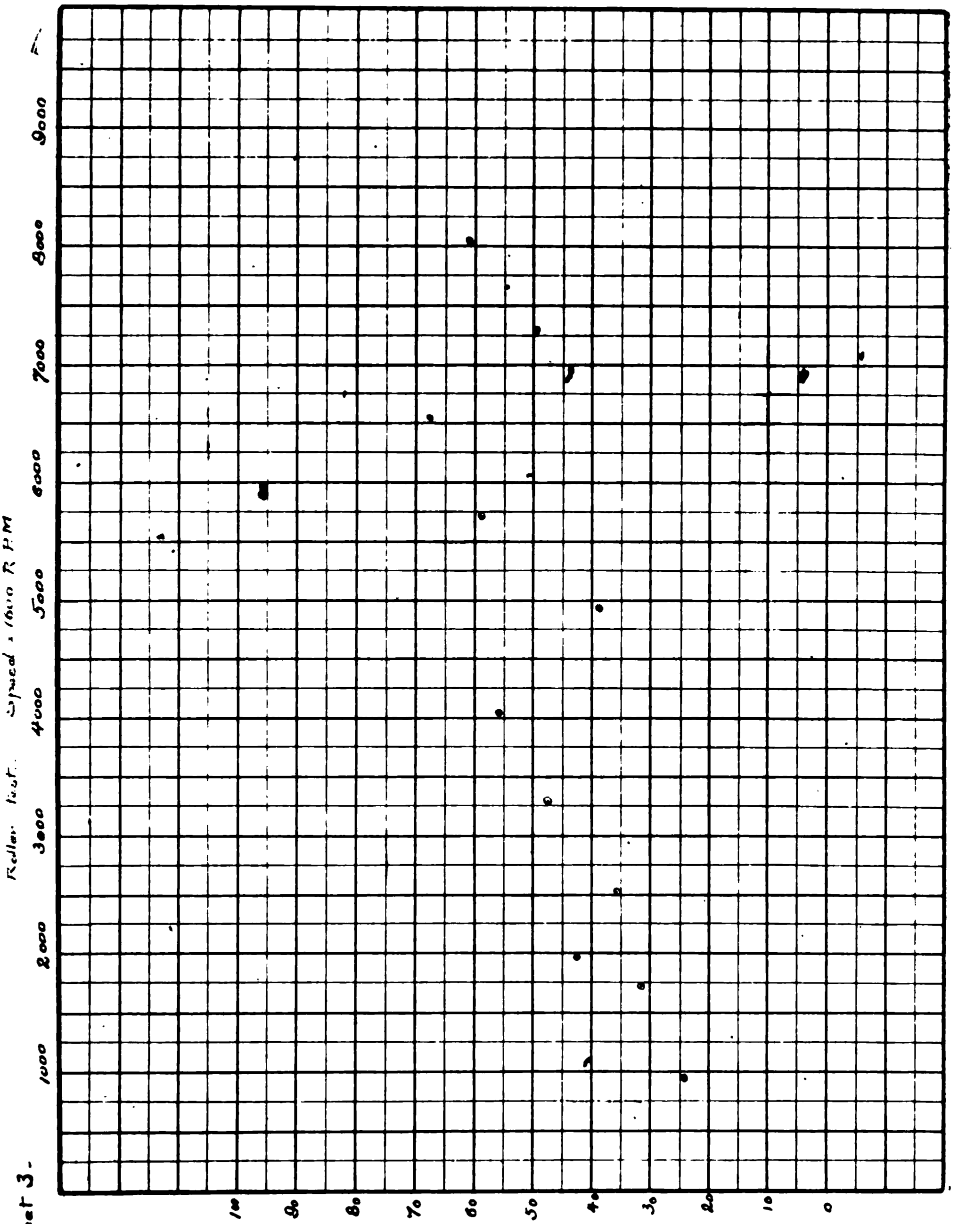
BALL


Roller Bearing Test
Sheet 2


Roller test. Speed: 1600 R.P.M
1000
2000
3000
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5000
6000
7000
8000
9000
100
90
80
70
60
50
40
30
20
10
0

Sheet 3.

then case-hardened and ground. No further grinding or other treatment to produce a greater degree of accuracy was given to any of the bearings used. Four tests were made at each of four speeds for every load, so that sixteen tests were made for each load. With some of the roller-bearing tests, where the results varied markedly, a greater number were made. In the curve of tests showing the comparative friction, each point is the average of four tests, so the position of the line is the result of sixteen tests. The loads were varied from fifty pounds to five hundred pounds. It was found that while the friction increased with the load in a nearly constant ratio for the balls, for the rolls there was a great variation at and after three hundred pounds. This is shown by the points on sheet 2. An examination of the shaft showed that it was being torn away in small flakes under the 300-pound load, and this tearing increased as the load was made greater. At 500 pounds the shaft was torn away quite rapidly, especially at the higher speeds, and after a few minutes' operation, a ridge was formed on the outside edges of the path of the rollers. This ridge had to be filed down on one side before the cage and rollers could be removed from the shaft. Neither the rolls nor their hardened steel race were affected, though, as already mentioned, the sides of the cage were cut by the ends of some of the rolls. Of the fourteen rolls in one cage, this wearing occurred at both ends of four of them. In making measurements on the dynamometer, a scale reading to fractions of ounces was used, so in plotting curves the unit used was the ounce.

The diagram of the friction curve for the roller bearings shows the points for the measurements taken at each load to be within spaces that increase slightly until the 250-pound load is passed, when the spaces between points increase in such manner as to show that the pull on the scale was due to more than the friction. It will be seen, however, that most of them seem to fall below the line made by the curve up to that point, if the line were produced. The points were so distributed that a curve drawn through the average position would not mean much. Why they fell so low in some cases I was unable to determine.

The diagram for the friction of the ball bearings shows the points within small spaces up to the 500-pounds load. How much farther this would continue with the kind of bearing used I did not determine, though I found on another test made on smaller balls and bearings, that both balls and bearings began to pit soon after the load exceeded 500 pounds.

and that this pitting was very marked at 700 pounds. The small pieces torn from the balls and races were very different in shape from the flakes torn from the shaft by the rolls.

The diagram giving a comparison of the friction line of the two kinds of bearings shows the friction of the roller bearing to be more than twice as great as that of the ball bearing. Calculations from the figures taken during the tests gave the co-efficient of friction for the ball bearings used to be .00475, or less than one-half of one per cent., while that for the roller bearings was .014, or nearly one and one-half per cent. I have no doubt that if the shaft used was of steel, hardened and ground, as the rest of the parts were, that the friction would be reduced. As the shaft was torn by the rolls, new parts were brought into contact and a marked drop of the pull occurred.

Bearing-Testing Dynamometer.

By M. J. Golden.

In making some tests to determine the amount of power lost by friction in different forms of shaft bearings, so much trouble was experienced in separating the loss in other parts of the apparatus used from that in the part being tested, when the regular transmission type of dynamometer was used, that the apparatus described here was devised for that purpose. It was tried in various forms experimentally before the present form was adopted. One of the rougher forms was described here last year in connection with a report then made on some bearing tests. In such tests the whole friction is so small that it is difficult to separate the friction due to the part being tested from that of the rest of the apparatus.

The machine as now used consists of a cast iron frame, made heavy enough to be stiff and to absorb a large portion of the vibration due to the rapidly moving parts. To the top of the frame is bolted a cast-iron table with planed surface. On this table are bolted two carriages, shown in the illustration at (a), that are fitted with ball bearings, in which a spindle or shaft revolves. These bearings are used because of the ease of alignment with them, and by fastening a set collar on each side of

one of them end thrust is provided for. Different sizes of spindle may be used by having spare sleeves to be slipped on the smaller sizes and into the bearings.

The special features of the machine are the way in which the load is applied and measured. This is accomplished by having a stiff, cast-iron yoke (b), through the center of which the spindle passes. The ends of

the yoke project over the ends of the table and are provided with hardened steel knife edges (c) on which rods are hung, and the weights used for the load are suspended on these rods (d). The knife edges on which the weights are hung are on a line that passes an eighth of an inch above the center of the yoke, and as the rods are free to move on the edges, a nice balance of the yoke can be maintained. The bearing to be tested is placed in a cage that is fitted in the center of the yoke, and the shaft or spindle is revolved inside of it. The tendency of the yoke to revolve

around the spindle, due to the friction of the bearing, is met in this way: At nine inches from the center of the yoke, and on the line of knife edges for weights, is an inverted knife edge (f). Above this a sensitive scale (e) is suspended and a link connection is made between the scale and the knife edge. The tendency of the yoke to revolve is met by the pull of the scale and the amount of the pull is registered on the scale.

Variation in speed is arranged for by placing on the end of the spindle that passes through the yoke a cone pulley of four steps (g), and this is driven by a belt from a corresponding cone pulley on a shaft (h) in the lower part of the frame. On this shaft is another cone pulley of three steps (j) driven from one on a countershaft. So a wide range of speeds can be gotten, and from a countershaft driven at 300 turns in a minute the spindle in the yoke has been made to revolve at speeds varying from thirty turns in a minute to 9,000 turns in a minute.

On the assumption that in some forms of bearings the suspension of the yoke on the spindle would be from some point near the top of the bearing, a yoke was made in which the knife edges for the weight rods could be raised and lowered, and some tests were made on different types of bearings with the edges at places above and below the center of the yoke; but though the suspension varied from the top to the bottom of the spindle no measureable change could be found.

To overcome the difficulty of finding the zero point for any test, a slightly greater weight was given to the scale side of the yoke than to the other side; and any one reading was made by driving the spindle first in one direction and then in the other, as this would give the amount of pull due to friction on the scale, as from the point found when driving one way to the corresponding point found when driving the other would be twice the amount that would be gotten when driving in either way alone.

The Toepler-Holtz Machine for Roentgen Rays.

By J. L. Campbell.

A Proposed Notation for the Geometry of the Triangle.

By Robt. J. Aley.

Everyone who has studied geometry very long has felt the need of a uniform notation. Much time is wasted in getting acquainted with the notations of different authors. This is especially true in modern pure geometry, where the figures are necessarily complex. The notation here proposed has been successfully used in the schoolroom. It is partially used by several well-known writers on modern geometry. It is hoped that its simplicity and system will commend it.

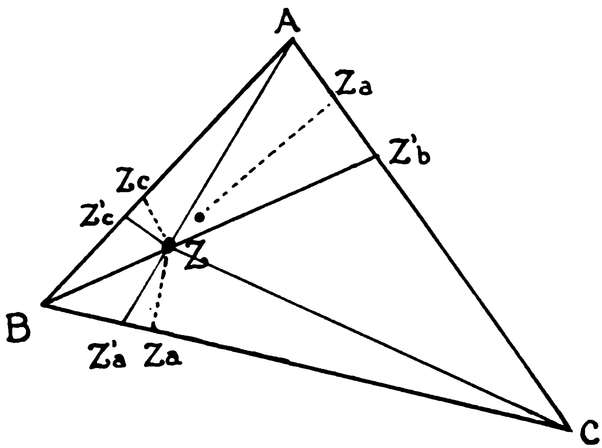
Let the triangle always be lettered ABC and in the usual positive direction of mathematics, i. e. counter clock-wise. Designate the sides, opposite the angles, a, b, c, and when necessary to refer to them by number, use 1, 2, 3. Particular points are made the basis of the notation. An example will make the method clear.

Suppose Z is some particular point. In studying such a point we usually need the points of intersection with the sides of the lines from the vertices through Z, and also the feet of the perpendiculars from Z to the sides. We designate the first set of points as Z'_a, Z'_b, Z'_c and the second as Z_a, Z_b, Z_c.

For the particular points, the symbol most frequently used has been in general selected.

A	B	C	=	vertices of the fundamental triangle.
	M		=	centre of the circumcircle.
M_a	M_b	M_c	=	mid-points of the sides of the triangle.
	I		=	centre of the inscribed circle.
I_1	I_2	I_3	=	centres of 1st, 2d, 3d escribed circles.
I_a	I_b	I_c	=	points of contact of sides with inscribed circle.
I'_a	I'_b	I'_c	=	points of intersection of AI, BI, CI with the sides.
I_{1a}	I_{1b}	I_{1c}	=	points of contact of sides with 1st escribed circle, and so on.
	G		=	centroid of ABC.
G_a	G_b	G_c	=	feet of perpendiculars to the sides from G.
	K		=	symmedian point (Grebe's).
K_a	K_b	K_c	=	feet of perpendiculars to the sides from K.
K'_a	K'_b	K'_c	=	points of intersection of AK, BK, CK with sides.
K_1	K_2	K_3	=	1st, 2d and 3d ex-symmedian points.
K_{1a}	K_{1b}	K_{1c}	=	feet of perpendiculars to the sides from K, and so on.
K'_{1a}	K'_{1b}	K'_{1c}	=	points of intersection of AK_1, BK_1, CK_1 with sides, and so on.
	H		=	ortho centre.

H_a	H_b	H_c	=	feet of altitudes of triangle.
	Ω_1	Ω_2	=	the Brocard points.
A_1	B_1	C_1	=	Bocard's 1st triangle.
A_2	B_2	C_2	=	Brocard's 2d triangle.
	F		=	centre of the nine points circle.
	Q		=	Nagel's point.
Q_1	Q_2	Q_3	=	associated Nagel points.
A_3	B_3	C_3	=	Nagel's triangle.
A_4	B_4	C_4	=	Schwatt's triangle.
	N		=	Tarry's point.
	R		=	Steiner's point.
A'	B'	C'	=	mid-points of the arcs of the circumcircle subtended by the sides of the triangle.
A''	B''	C''	=	opposite points from $A'B'C'$ on circumcircle.
	P		=	Gergonne point.
P_1	P_2	P_3	=	the associated Gergonne points.
a	b	c	=	the sides of the triangle.
h_1	h_2	h_3	=	the three altitudes.
m_1	m_2	m_2	=	the medians.
	r		=	radius of incircle.
r_1	r_2	r_3	=	radius of excircle.
	s		=	$\frac{1}{2}(a + b + c)$.
s_1	s_2	s_3	=	$s - a$, $s - b$, $s - c$.
	R		=	radius of circumcircle.
$\triangle$	D		=	area of triangle.



Some Circles Connected with the Triangle.

By Robt. J. Aley.

In my study of the geometry of the triangle I have frequently felt the need of an available collection of the circles connected with it. So far as I know, no such collection is extant. The following list, which is by no means complete, is offered as the beginning of what it is hoped may grow into an exhaustive collection.

1. *Circumcircle.*—The circle that passes through the vertices A, B, C of the triangle. Centre at M, the point of concurrence of perpendiculars erected at the mid-points of the sides. R, the radius $= \frac{abc}{\Delta}$.

2. *Incircle.*—The circle which is tangent internally to the three sides of the triangle. Centre at I, the point of concurrence of the three internal bisectors of the angles of the triangle. r, the radius $= \frac{\Delta}{S}$.

3. *Excircles.* The three circles which are tangent externally to one side and internally to two sides of the triangle. Centres are I_1, I_2, I_3, the points of concurrence of the external bisectors of the angles with the internal bisectors of A, B, C, respectively. The radii are $r_1 = \frac{\Delta}{s-a}$, $r_2 = \frac{\Delta}{s-b}$ and $r_3 = \frac{\Delta}{s-c}$.

4. *Nine Points Circle.*—The circle which passes through the midpoints of the sides of the triangle, the feet of the perpendiculars, and the midpoints of the parts of the altitude between the orthocentre and the vertices. Centre is at F, the midpoint of IM. The radius is ½ R. It is tangent to the incircle and to each of the excircles.

5. *Brocard Circle.*—The circle whose diameter is the line joining the circumcentre M, to the symmedian point K. It passes through the two Brocard points $\Omega_1 \Omega_2$ and through the vertices of Brocard's first and second triangles. Centre at midpoint of MK.

6. *Cosine Circle.*—The circle which passes through the six points of intersection of antiparallels through K with the sides. Centre is at K (Symmedian point).

7. *Ex-Cosine Circles.*—The three circles which have K_1, K_2, K_3 (ex-symmedian points) for centres, and which pass through B, C; C, A; and A, B, respectively.

8. *The Lemoine Circle.*—The circle which passes through the six intersections of parallels through K with the sides of the triangle. The centre is at the mid-

point of MK. The centre coincides with the centre of Brocard's Circle. The radius is equal to $\frac{1}{2}\sqrt{R^2+\rho^2}$ where ρ is the radius of the Cosine Circle. The segments cut out of the sides of the triangle by the circle are proportional to the cubes of the sides of the triangle. For this reason the circle is sometimes called the *Triplicate Ratio Circle.*

9. *Taylor's Circle.*—The circle which passes through the six projections of the vertices of the pedal triangle on the sides ot the fundamental triangle.

10. *Tucker's Circles.*—The circle that passes through six points determined as follows: If on the lines KA, KB, KC, points A′, B′, C′ are taken so that $KA':KA=KB':KB=KC':KC=$ a constant, then the six points above referred to are the intersections of B′C′, C′A′ and A′B′ with the sides of ABC.

The centre is at the midpoint of the line joining M and the circumcentre of A′B′C′.

The circum-, Lemoine, Cosine and Taylor Circles are particular cases of Tucker Circles.

11. *Orthocentroidal Circle.*—The circle of similitude of the circum and nine-points circle. Centre at the midpoint of HG. Radius is $\frac{1}{2}$ HG.

12. *McCay's Circles.*—The three circles which circumscribe the triangles B_2C_2G, C_2A_2G, and A_2B_2G, respectively. ($A_2B_2C_2$ is Brocard's second triangle and G is the centroid.

13. *Polar Circle.*—This is the circle with respect to which the triangle is self-conjugate. Its centre is at H. It is real when H is outside the triangle, evanescent when H is at a vertex, and imaginary when H is within the triangle.

14. ——— *Circle.*—The circle on IM as diameter. It passes through A_5, B_5, C_5, which are the midpoints of AA′, BB′, CC′, respectively. (Proceedings Indiana Academy of Sciences, 1898, page 89.)

15. *Adam's Circle.*—The circle which passes through the six points determined by the intersection with the sides of the triangle of the lines through the Gergoume Point P, parallel to I_aI_b, I_aI_c, I_cI_a, respectively. The centre is at I.

16. ——— *Circles.*—Lines through P_1, P_2, P_3 (the associated Gergoume points), parallel to the sides of $I_{1a}I_{1b}I_c$, $I_{2a}I_{2b}I_{2c}$, and $I_{3a}I_{3b}I_{3c}$, respectively, determine sets of six points on the sides which are concyclic. The centres of these three circles are at I_1, I_2, and I_3. These circles might be called the associated Adam's circles.

The Point P and Some of Its Properties.

By Robert J. Aley.

P is the point of concurrence of the lines drawn from the vertices of a triangle to the points of contact of the inscribed circle with the sides. It has been called the Gergonne Point. The ratios of the distances of the point P from the sides are $\frac{1}{a(s-a)} : \frac{1}{b(s-b)} : \frac{1}{c(s-c)}$ (Aley, Contributions to Geom. of the Triangle, p. 10 (10)). From these ratios the actual distances of the point from the sides is easily found to be

$$PP_a = \frac{2\Delta(s-b)(s-c)}{a\Sigma(s-a)(s-b)}$$

$$PP_b = \frac{2\Delta(s-c)(s-a)}{b\Sigma(s-a)(s-b)}$$

$$PP_c = \frac{2\Delta(s-a)(s-b)}{c\Sigma(s-a)(s-b)}$$

P and Q (Nagel's Point) are isotomic conjugates and they are collinear with Z, the isotomic conjugate of I (incentre) (Ibid., page 8, III).

P_1 (the isogonal conjugate of P), Z_1 the isogonal conjugate of Z and K are collinear (Ibid., page 13, IV).

P_1, I and M are collinear.

The ratios of P_1 are $a(s-a) : b(s-b) : c(s-c)$ (Ibid., p. 3, 81).

From these the actual distances of P_1 from the sides is readily found to be

$$P_1P_{1a} = \frac{2\Delta a(s-a)}{S\Sigma a^2 - \Sigma a^3}$$

$$P_1P_{1b} = \frac{2\Delta b(s-b)}{8\Sigma a^2 - \Sigma a^3}$$

$$P_1P_{1c} = \frac{2\Delta c(s-c)}{8\Sigma a^2 - \Sigma a^3} \left\{ \text{Ibid., page 14, (7)} \right\}.$$

It is well known that

$$II_a = \frac{\Delta}{s}$$

$$II_b = \frac{\Delta}{s}$$

$$II_c = \frac{\Delta}{s}$$

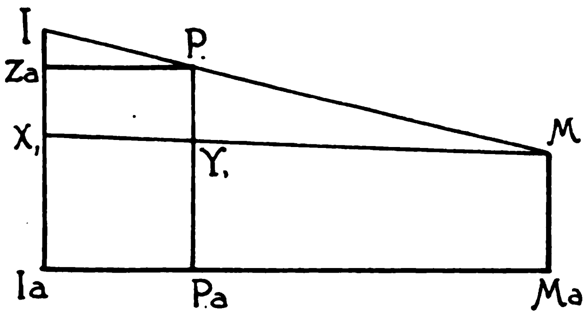
The ratios of M are $a(-a^2+b^2+c^2) : b(a^2-b^2+c^2) : c(a^2+b^2-c^2)$.

From these ratios it is easily found that

$$MM_a = \frac{a(-a^2+b^2+c^2)}{8\Delta}$$

$$MM_b = \frac{b\ a^2-b^2+c^2}{8\Delta}$$

$$MM_c = \frac{c(a^2+b^2-c^2)}{8\Delta}$$



$$IZ = II_a - P_I P_{I_a}$$

$$= \frac{\Delta}{S} - \frac{2\Delta a(S-a)}{S\Sigma_a^2 - \Sigma_a^3}$$

$$= \frac{\Delta}{S(S\Sigma_a^2 - \Sigma_a^3} \left\{ S\Sigma_a^2 - \Sigma_a^3 - 2aS(S-a) \right\}$$

$$= \frac{\Delta}{S(S\Sigma_a^2 - \Sigma_a^3)} \left\{ a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3 \right\}$$

$$IX = II_a - MM_a$$

$$= \frac{\Delta}{S} - \frac{a(-a^2-b^2+c^2)}{8\Delta}$$

$$= \frac{1}{8S\Delta} \left\{ 8\Delta^2 - aS(-a^2+b^2+c^2) \right\}$$

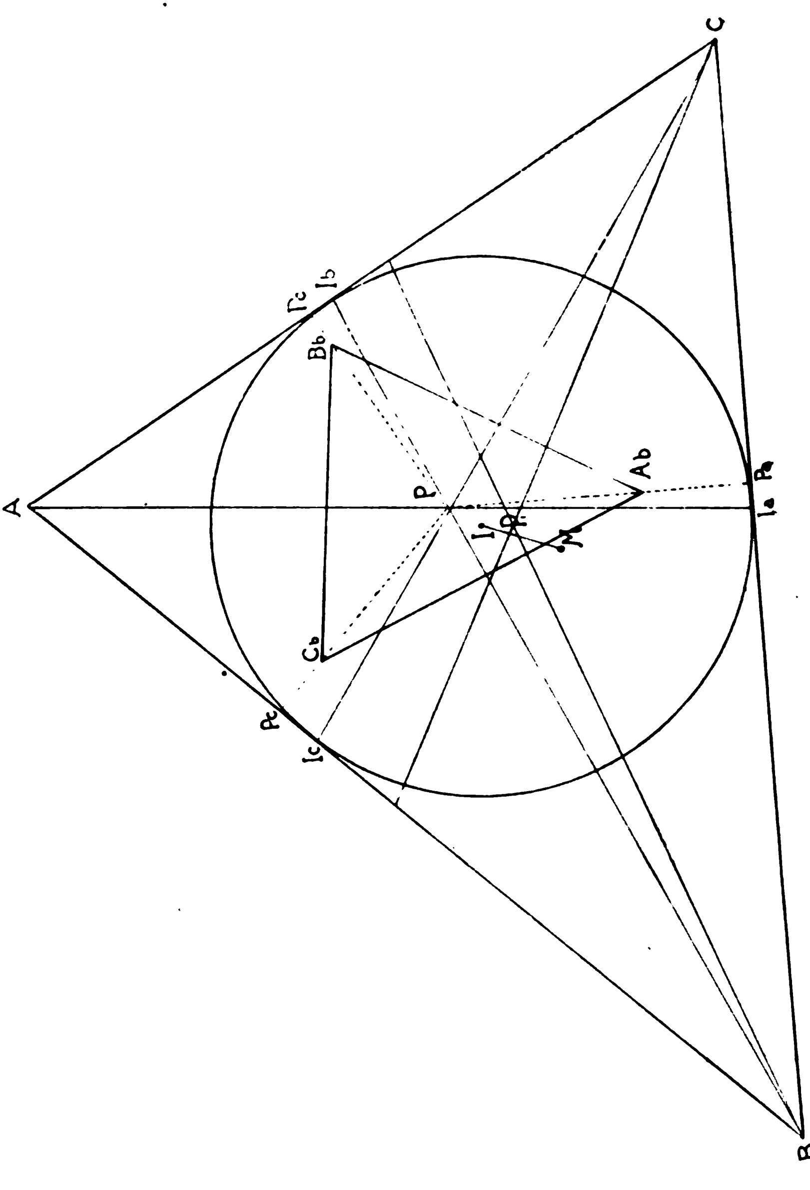
$$= \frac{8}{8S\Delta} \left\{ 8(S-a)(S-b)(S-c) - a(-a^2+b^2+c^2) \right\}$$

$$= \frac{8}{8S\Delta} \left\{ a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3 \right\}$$

$$Iz : Ix = \frac{\Delta}{s(s\Sigma a^2 - \Sigma a^3)} (a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3) :$$

$$: \frac{8}{8s\nabla} (a^2b + a^2c + b^2c + bc^2 - 2abc - b^3 - c^3) =$$

$$= 8\Delta^2 : s(s\Sigma a^2 - \Sigma a^3).$$


A
B
C
Ab
Bb
Cb
P
I
Ia
Ib
Ic

Similarly

$$IZ_2 : IX_2 = 8\Delta^2 : s(s\Sigma a^2 - \Sigma a^3)$$

And the same is true of $IZ_3 : IX_3$.

The points are therefore collinear.

$IZ_1 : IX_1 = IP_1 : IM$

$IP_1 : IM = 8\Delta^2 : S(S\Sigma a^2 - \Sigma a^3)$

$$IP_1 : P_1M = IP_1 : IM - IP_1 = 8\Delta^2 : s(s\Sigma a^2 - \Sigma a^3) - 8\Delta^2 =$$
$$= (-a+b+c)(a-b+c)(a+b-c) : s\Sigma a^2 - \Sigma a^3$$
$$-(-a+b+c)(a-b+c)(a+b-c).$$

The ratio of division is too complex for ordinary use.

If upon the lines PP_a, PP_b, PP_c equal distances from P be taken the triangle $A_6B_6C_6$ thus formed is similar to Nagel's triangle $A_3B_3C_3$.

For $\angle A_6PB_6 = \Pi - C$

And $\angle PA_6B_6 = \angle PB_6A_6 = \frac{1}{2}\,\xi(\Pi - \angle A_6PB_6) = \frac{1}{2}\,C$.

Similarly the $\angle PB_6C_6 = \frac{1}{2}\,A$.

And hence $\angle A_6B_6C_6 = \frac{1}{2}\,A + \frac{1}{2}\,C = \frac{1}{2}\,(A + C)$.

Likewise $\angle B_6C_6A_6 = \frac{1}{2}\,(A + B)$

And $\angle B_6A_6C_6 = \frac{1}{2}\,(B + C)$.

But these are the angles of Nagel's triangle and therefore $A_6B_6C_6$ is similar to $A_3B_3C_3$.

P is the symmedian point of the triangle $I_aI_bI_c$. (Proc. Edinburgh Math. Soc., Vol. XI., page 105).

If through P lines are drawn parallel to the I_aI_b, I_bI_c, I_cI_a respectively, the six points of intersection with the sides are concyclic. The circle is call Adam's circle.

Diamond Fluorescence.

By Arthur L. Foley.

[Abstract.]

Some three or four years since, I had occasion to cut a large number of photographic dry plates to smaller sizes. They were cut in the usual way with a diamond, and on the side of the plate opposite the film. In developing it was noticed that the film, to a breadth of a few millimeters along the edge of the plate, turned dark, as if exposed to light.

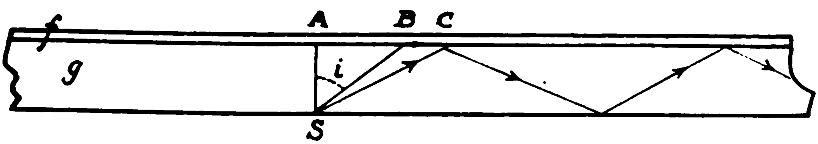
Several possible explanations suggested themselves:

1. The breaking of the glass might produce momentary fluorescence and a fogging of the film near the break.

2. The breaking or tearing of the film might result in some sort of change in its character.

3. The scratching of the diamond might set up mechanical disturbances or vibrations in the glass and these might affect the film.

4. The friction between the diamond and the glass might cause a momentary fluorescence along the line traced by the diamond, and the radiation might penetrate the glass and fog the film on the other side.



The last is the true explanation.

The first and second suggested explanations were thrown aside at once, for the dark line in the film was found to appear along the diamond-scratched line, whether the plate was broken or not. That the third explanation was not the true one was shown in several ways. The breadth and intensity of the dark lines did not appear to depend upon the depth of the cut or the rapidity with which it was made. The line was always of the same breadth on the same plate, but of different breadths on different plates. Moreover, the film always developed first on the side next the glass, which would not have been the case had the effect been due to any sort of strain or mechanical disturbance. The effect was noticeable on the most rapid plates only. Seed's "Gilt Edge" were used in most cases.

Let f represent the film on a section of the glass plate g, perpendicular to the diamond scratch s. Let us regard s as a source of radiation.

All rays (as s c) lying outside the critical angle i are totally reflected and hence do not affect the film. Those having an incident angle less than i penetrate the film and fog it if they are of sufficient intensity. The breadth of the fogged line is therefore—

$$b=2\ \overline{AB}=2\ t.\ \tan.\ i.$$

where t is the thickness of the glass plate and i is the critical angle for glass and the film substance.

Taking the indices of refraction of glass and gelatine for violet light, it was found that the equation is correct to within the degree of accuracy with which the various measurements could be made.

It was thought that the light produced by the friction of the diamond and glass might be sufficient to affect the eye. Nothing could be seen when the experiment was tried, although the observers had taken the precaution of staying in an absolutely dark room for an hour to render the eye as sensitive as possible. But this does not prove that no light resulted from the friction. A very feeble light would be sufficient to fog the plate when coming from a point so near the film. Besides, the fluorescence might have consisted of waves too short to affect the eye. In the formula I used the indices of refraction of violet light in order to obtain the value of the critical angle. For shorter waves the indices would be different, but their ratio probably would not be greatly different from the value used.

Latėr experiments have shown that fluorescence does not always occur when a diamond is drawn across a dry plate. I am not yet ready to say whether it is due to differences in different diamonds, to differences in the nature of the glass, or to changes in temperature, electrification, etc. I hope to be able to report more definitely at a future meeting.

Some Experiments on Locomotive Combustion.

By J. W. Shepherd.

Through the courtesy of the T. H. & I. Railroad officials, a study of the combustion in a locomotive while in operation was undertaken, the study being made from the analyses of the stack gases. The analyses were made with a modified Orsat apparatus.

The experiments were conducted on the large Schenectady passenger engines and on fast runs between Terre Haute and St. Louis, and Terre Haute and Indianapolis.

The apparatus for sampling the gases consisted of a half-inch gas pipe extending eight or ten inches into the center of the stack and bent uniformly following the outside of the stack to near its base, where another bend led it back to the cab on the fireman's side. Through this pipe, with the proper connections inside the cab, the gases were drawn into bottles by means of a steam jet. The bottles were fitted with ground-glass stoppers. The end of the gas pipe within the stack was fitted with a thimble, the lower end of which was solid steel and the sides perforated. This particular fitting was found to be essential to the successful operation of the apparatus.

Samples were taken in three different ways: (1) For periods of one to two minutes by displacement of water; (2) for continuous samples, from Terre Haute to terminals of road if desired, by displacement of water, and (3) for any period of time (brief as desired and whenever desired) by air displacement. In methods Nos. 1 and 2 the water displaced was acidulated with sulphuric acid. In method No. 3 the gas was passed five times before the bottle was disconnected from sampler.

Method No. 1 was not satisfactory, because the fireman did not fire normally during the sampling.

Method No. 2 showed that the value of a fire does not always vary directly as the increase of carbon dioxide and decrease of free oxygen in the stack gases. Samples Nos. 1 and 10 in the following table will serve as an illustration. No. 1 was taken continuously from Terre Haute to Effingham, Ill. (sixty-eight miles), and No. 10 from Effingham to East St. Louis (100 miles), both on same train, but different crews. No. 1 required less coal per car mile than No. 10. It is to be observed that No. 10 shows a percentage of carbon monoxide, which means that the rapid evolution

of hydrocarbons resulted in a fuel loss, and is largely attributable to the kind of firing. No. 9 was also a continuous sample, between Terre Haute and Indianapolis, and showed the least coal consumption per car mile of any. This must mean that more volatile matter escaped in No. 1 than No. 9. Carbon monoxide was not determined in sample No. 1, but No. 9 was analyzed for it.

Samples Nos. 2, 3 and 4 furnish an interesting study on the evolution of the volatile-combustible matter.

Samples Nos. 5, 6, 7 and 8 show more strikingly the rate of volatilization. While the percentage of carbon dioxide in samples Nos. 5, 6 and 7 remains the same, it is to be noticed that the percentage of free oxygen decreases, which means increased volatilization.

As a rule samples show less uniformity than shop tests on account of the jarring motion of the locomotive.

It is intended to make other tests in conjunction with temperature determinations with a view of determining percentage losses.

No.	CO_2	CO	Free O	Kind of Firing.	Interval During Which Sample Was Taken From Time Fire Was Built.
1	9.1	......	8.8	Medium	Continuous.
2	14.0	0.8	2.6	Heavy.............	20–30 seconds.
3	13.7	0.5	2.6	Heavy.............	35–45 seconds.
4	12.6	0.0	5.4	Heavy.............	50–60 seconds.
5	10.0	......	8.9	One shovel.........	2–3 seconds.
6	10.0	......	8.4	One shovel.........	3–4 seconds.
7	10.0	......	5.5	One shovel.........	4–5 seconds.
8	9.4	......	8.7	One shovel.........	5–6 seconds.
9	7.9	0.0	10.4	Light..............	Continuous.
10	11.0	0.7	5.24	Heavy.............	Continuous.

Medium fire, 2–3 scoops.
Light fire, 1–2 scoops.
Heavy fire, 4–5 scoops.

Some Ionization Experiments.

By P. N. Evans.

The proportion existing between the ionized and un-ionized molecules of an electrolyte in (aqueous) solution, is represented by the equation $a \cdot b = k \cdot c$, in which a, b, and c are the concentrations of the anions, kathions and un-ionized molecules of the electrolyte, respectively, and k a constant depending on the nature of the electrolyte and independent of the concentration for moderately or highly dilute solutions.

Supposing this equilibrium to have become established, which is the case in an exceedingly brief time, if not instantaneously, any addition of either kind of ion concerned, the quantity of solvent remaining the same, must result in an increased value for its concentration and produce a corresponding increase in the number and concentration of the un-ionized molecules; for, k being a constant, any increase in the value of a or b will involve an increase of that of c if the equilibrium is to be maintained.

If to a saturated solution of an electrolyte there be added a second soluble electrolyte having an anion or kathion in common with the first, there must result a state of supersaturation with regard to the first electrolyte or a separation of a portion of it in insoluble form.

Many examples of this are familiar to all. For instance, a saturated solution of sodium chloride is instantly precipitated by the addition of concentrated hydrochloric acid, in spite of the water that is added at the same time; on the other hand, the case is complicated and the precipitation assisted, probably by the chemical union taking place between the hydrochloric acid and some of the water, made evident by the evolution of heat, thus increasing all the concentrations by removing (chemically changing) some of the solvent. The same result is obtained and the same reasoning applies when calcium chloride is added to a saturated sodium chloride solution. The precipitation of sodium chloride is brought about without this complication of causes by the addition of crystallized potassium chloride (KCl) or anhydrous sodium sulphate (Na_2SO_4), and even crystallized sodium sulphate ($Na_2SO_4.10H_2O$) gives the same result in spite of the water added in the crystals.

Similarly, potassium chloride can be precipitated by hydrochloric acid, sodium chloride ($NaCl$), or potassium sulphate (K_2SO_4); and copper sulphate ($CuSO_4.5H_2O$) by cupric chloride ($CuCl_2.2H_2O$), copper nitrate ($Cu(NO_3)_2$.

$6H_2O$), or sulphuric acid; barium chloride ($BaCl_2.2H_2O$) by hydrochloric acid, or sodium chloride; calcium sulphate ($CaSO_4.2H_2O$) by sulphuric acid, potassium sulphate, calcium nitrate ($Ca(NO_3)_2.4H_2O$); lead chloride ($PbCl_2$) by hydrochloric acid, sodium chloride, potassium chloride.

In this list we have a very wide range of solubility: 100 parts of water dissolve NaCl 35, KCl 32, $CuSO_4.5H_2O$ 40, $BaCl_2.2H_2O$ 33, $CaSO_4.2H_2O$ .20, $PbCl_2$ .74 parts. It is not evident whether easily or difficultly soluble substances should respond more readily in the yielding of a precipitate under these conditions, for the much greater degree of supersaturation attainable with an easily soluble substance may be offset by the greater difficulty in disturbing this state of supersaturation.

The greater the solubility of the electrolyte added to the saturated solution, the more readily a precipitate should be obtained; and the higher the dissociation constant of the second electrolyte, the more probable is a marked result.

In spite of the apparently favorable conditions in this respect, all attempts to precipitate lead chloride from its solution by means of lead nitrate were in vain. A saturated solution is very readily prepared by warming the solution in contact with an excess of the salt, and then cooling, owing to the great difference in solubility in hot and in cold water. The immediate and copious precipitate produced in this solution by the addition of sodium or potassium chloride or hydrochloric acid seemed to indicate that the tendency to remain in the supersaturated condition was very slight in the case of this salt, yet the addition of lead nitrate crystals to the solution (saturated), even in the considerable quantity made possible by the ready solubility of the nitrate (48 parts in 100), failed to cause any precipitation, either immediately or on long standing, or even on adding a crystal of lead chloride to induce crystallization from the solution, supposing it to be supersaturated. Lead nitrate, like most normal salts, has a high dissociation constant, more than half that of the strongest acids in a .1 per cent. solution (calculated by Arrhenius from conductivity experiments by Kohlrausch). This fact, and its high solubility, should be most favorable to the precipitation of the lead chloride, on account of the considerable increase in the concentration of the lead ions made possible thereby.

In harmony with the usual similarity of barium to lead, a saturated solution of barium chloride showed no sign of precipitation with barium nitrate ($Ba(NO_3)_2$); as already stated, a precipitate was produced by the

addition of hydrochloric acid, or sodium or potassium chloride to the saturated barium chloride solution.

Similarly, potassium sulphate, though precipitated from its saturated solution by the addition of potassium chloride or sodium sulphate, gave no precipitate with sulphuric acid; and calcium sulphate was not thrown down by either sodium sulphate or ammonium sulphate but did separate slowly on the addition of potassium sulphate and more quickly with sulphuric acid.

Apparently, then, in these cases, the number of un-ionized molecules of the first is not increased by the addition of the second electrolyte, and the only plausible explanation seems to be that in these cases double salts are formed; e. g., lead-chloride-nitrate ($PbClNO_3$), barium-chloride-nitrate ($BaClNO_3$), hydrogen-potassium-sulphate ($HKSO_4$), calcium-sodium-sulphate ($CaNa_2(SO_4)_2$?), and calcium-ammonium-sulphate ($Ca(NH_4)_2(SO_4)_2$?).

Taking the case of lead chloride as an example, the addition of the lead nitrate must immediately increase the number of lead ions, but at the same time diminishes both this and the number of the chlorine ions by permitting the formation of lead-chloride-nitrate, so that the value of the product of the concentrations of lead and chlorine ions is not thereby increased, thus causing no rise in value of the concentration of the lead chloride, and, therefore, no separation of this substance as a precipitate. It does not follow that this peculiarity of behavior must accompany the formation of a double salt under similar circumstances, however, for it may be that the increase of the concentration of one kind of ion concerned may more than counterbalance the simultaneous decrease in this and that of the other kind of ion involved; this is simply a question of the value of the dissociation constants of the electrolytes present.

It seems probable that double salts exist in solutions whenever there is a polyvalent acid in presence of two or more bases or a polyvalent base in presence of two or more acids, though other evidence of the existence of most of these compounds is at present lacking. Since, however, we know and recognize the existence of only those double salts which separate out from solutions of their constituents rather than these constituents in distinct crystals, the evidence so far accepted for the existence of such compounds is of a very limited kind, namely, only their solubility relative to that of their constituents. In other words, if these separate in preference to the double compound, the latter does not exist so far as this kind of evidence is concerned.

Now, supposing that in a solution of equivalent quantities of the constituents the dissociation constants of these and the double salt are such that approximately equal numbers of molecules of the three kinds exist un-ionized, and the solution be concentrated, the double salt will separate if its molecular solubility (solubility divided by molecular weight) is less than that of either constituent, but not otherwise. Of course, it is not probable that the constants are such as to even approximately produce a condition like that imagined in the example just described, but inasmuch as normal salts do not differ very widely in their dissociation constants, the facts may be nearly enough in harmony with the supposition to make a study of these molecular solubilities not without interest in this connection, though the data available are not so numerous as might be desired.

An examination of the solubilities of twelve double salts selected at random showed the facts to be in accordance with this theory without a single exception. The figures are given in the following table, the formulas selected being those of the substances separating out as crystals from their solutions.

Formula.	*a. Molecular weight.*	*b. Solubility in 100 parts water.*	$b \div a \times 100$
K_2SO_4	174	12.5	7.2
$Al_2(SO_4)_3.18H_2O$	665	85	12.8
$KAl(SO_4)_2.12H_2O$	474	9.5	2.0
$(NH_4)_2SO_4$	132	77	57.6
$Al_2(SO_4)_3.18H_2O$	665	85	12.8
$(NH_4)Al(SO_4)_2.12H_2O$	452	9	2.0
K_2SO_4	174	12.5	7.2
$Cr_2(SO_4)_3.18H_2O$	717	120	16.7
$KCr(SO_4)_2 12H_2O$	500	20	4.0
$(NH_4)_2SO_4$	132	77	57.6
$Cr_2(SO_4)_3.18H_2O$	717	120	16.7
$(NH_4)Cr(SO_4)_2.12H_2O$	478	over 12	over 2.5
K_2SO_4	174	12.5	7.2
$Fe_2(SO_4)_3.9H_2O$	562	over 80	over 14.1
$KFe(SO_4)_2.12H_2O$	503	20	4.0

Formula.	*a. Molecular weight.*	*b. Solubility in 100 parts water.*	*b ÷ a × 100*
$(NH_4)_2SO_4$	132	77	57.6
$FeSO_4.7H_2O$	278	60	21.6
$(NH_4)_2Fe(SO_4)_2.6H_2O$	392	17	4.3
NH_4Cl	53.4	33	61.8
$SnCl_4.5H_2O$	350	over 1900	over 543
$(NH_4)_2SnCl_6$	366	33	9.0
K_2SO_4	174	12.5	7.2
$CaSO_4.2H_2O$	172	0.205	0.12
$CaK_2(SO_4)_2.H_2O$	328	0.25	0.08
K_2SO_4	174	12.5	7.2
$CoSO_4.7H_2O$	280	58	20.7
$K_2Co(SO_4)_2.6H_2O$	437	19	4.3
K_2SO_4	174	12.5	7.2
$NiSO_4.7H_2O$	281	67	23.9
$K_2Ni(SO_4)_2.6H_2O$	437	5.3	1.21
KCl	75	32	42.6
$MgCl_2.6H_2O$	203	130	64.0
$KMgCl_3$ $6H_2O$	278	64.5	23.2
K_2CO_3	138	110	80.0
$Na_2CO_3.10H_2O$	286	21	7.34
$KNaCO_3.6H_2O$	230	13	5.6

Synthesis of 2.3,3-Trimethyl Cyclo-Pentanone, a Cyclic Derivative of Camphor.

By W. A. Noyes.

When a solution of the sodium derivative of methyl malonic ester and of the ethyl ester of γ-bromisocaproic acid in absolute alcohol is boiled on the water bath, about six per cent. of the brom-ester is converted into the ethyl ester of 2.3,3, tetramethyl-hexanoic 1, 2^1, 6-acid,

$$\begin{array}{l} \quad\; CH_3-C<\begin{smallmatrix}CO_2C_2H_5\\CO_2C_2H_5\end{smallmatrix} \\ \qquad\qquad | \\ \begin{smallmatrix}CH_3\\CH_3\end{smallmatrix}>C-CH_2CH_2CO_2C_2H_5. \end{array}$$

The free acid, obtained by saponification of the ester with caustic potash, loses carbon dioxide when heated to 200° and is converted into α-$\beta\beta$-trimethyl-adipic acid,

$$\begin{array}{l} \quad\; CH_3-CH-CO_2H \\ \qquad\qquad | \\ \begin{smallmatrix}CH_3\\CH_3\end{smallmatrix}>C-CH_2-CH_2CO_2H. \end{array}$$

When this acid is mixed with lime and distilled, 2.3,3-trimethyl cyclopentanone,

$$\begin{array}{llll} & CH_3-CH & - & CO \\ & \qquad\quad | & & \;| \\ & \qquad\quad | & & CH_2 \\ & \qquad\quad | & & \;| \\ \begin{smallmatrix}CH_3\\CH_3\end{smallmatrix}> & \qquad\quad C & - & CH_2, \end{array}$$

is formed. The oxime of this ketone was proved to be identical with the oxime of the ketone obtained by J. W. Shepherd and myself from α-hydroxydihydrocis-campholytic acid. This synthesis establishes, beyond reasonable doubt, the correctness of Bouveault's formula for camphor.

$$\begin{array}{lcl} & CO & -\;CH_2 \\ & | & \quad\;| \\ CH_3- & C & -\;CH \\ & | & \quad\;| \\ & | & \quad CH_2 \\ & | & \quad\;| \\ \begin{smallmatrix}CH_3\\CH_3\end{smallmatrix}> & C & -\;CH_2. \end{array}$$

The details of the investigation appear in the American Chemical Journal, Vol. 23, p. 128.

Contributions to the Flora of Indiana. VI.

By Stanley Coulter.

In view of the publication in the near future of a catalogue of the phanerogamic flora of the State, this contribution is limited to a discussion of a few families, concerning which we have need of further knowledge. Each of these families, despite its familiarity, presents especial difficulties in the discrimination of species, difficulties which, as a rule, are not appreciated by the botanist who works remote from herbaria. Scant material and all too brief descriptions are responsible for a large proportion of the errors which have found their way into local lists.

POLYGONACEÆ.

Perhaps the greatest uncertainty exists in regard to the species of *Rumex* within the State. Of the eight species reported in the State, the following are undoubted: *R. Acetosella* L., *R. Britannica* L., *R. crispus* L., *R. obtusifolius* L., and *R. verticillatus* L.

Rumex altissimus Wood, reported from Jay, Delaware, Randolph and Wayne counties by Dr. Phinney, and from Dearborn County by Dr. Collins, is probably *R. Britannica* L., under mesophytic conditions. I have had several collections of the form referred to, *R. altissimus* Wood, for examination, and they take their place so naturally in a series of *R. Britannica* L., collected to show the effect of differing conditions upon the species, that it is impossible to avoid the suspicion that in many cases, at least, the forms referred to *altissimus* are really *Britannica*. I am unwilling to exclude the form from the State flora, not having seen the specimens of Dr. Phinney. I request, however, that if in any of the herbaria in the State there are forms referred to *altissimus*, they be examined with care and report made to me before the publication of the flora, instead of after its appearance.

R. occidentalis S. Wats. Reported from Jefferson County by J. M. Coulter, and from Clark County by Baird and Taylor, is probably to be excluded from the State list. There are no verifying specimens, and in fairly full collections of the genus made from those counties during two seasons the form does not appear. There is no especial reason why it should not be a member of our flora so far as its geographical distribution

goes, and I should not be surprised if it were found in some of the herbaria of the State. If so a prompt report should be made.

Rumex sanguineus L., reported from Jefferson and Clark counties, shows itself, upon an examination of the specimens, to be *R. crispus* L., with the veins of the foliage leaves of a somewhat reddish cast. The outer characters are evidently those of *R. crispus* L. In the absence of further data *R. sanguineus* must be excluded from the State list.

It may be suggested at this point that few forms respond in so marked a manner to changed conditions as the docks. These changes involve the general habit, venation, inflorescence and markings of the valves. The collection of a single species under varying conditions will sufficiently explain the doubt felt in admitting to the State flora, without further evidence, the three forms just discussed.

The genus *Polygonum* is represented by nineteen species in our bounds. The specimens examined show a number of incorrect references, which serve to render doubtful some statements as to the distribution of these forms. Among the more common errors of reference are the following: *P. lapathifolium* L., for *P. incarnatum* Ell. The larger and more erect forms of *P. aviculare* L., for *P. erectum* L., while very often *P. Hydropiper* L., and *P. punctatum* Ell. =(*P. acre* H. B. K.) are found associated upon a single herbarium sheet. An examination of the ordinary descriptions of these species will show how easily such errors in reference may be made, and how small is the likelihood of their subsequent correction unless especial attention is called to them.

P. Careyi Olney is reported only from Noble County by Van Gorder. This is to my mind a very doubtful reference. The recorded range of the species is northern Maine and New Hampshire to Pennsylvania and Ontario, which militates somewhat against the accuracy of the reference, while the wide range of variation in the nearly related species *P. amphibium* L., and *P. emersum* (Michx.) Britton, (=*P. Muhlenbergii* Watson) suggest its proper reference is to one of these forms. My own experience in the collection of Polygonums in the same region leads me to believe the form to be *P. emersum*. *P. Careyi* Olney is, therefore, to be omitted from the State list unless other data are available.

P. ramosissimum Michx. is reported only from Vigo County, by W. S. Blatchley. The recognized range of the plant includes the whole State. It is probable that it is of fairly general distribution and has been mistaken

for *P. erectum* L., from which it differs chiefly in its reduced and bract-like upper leaves.

P. tenue Michx., reported only from Tippecanoe County and Lake County, is in much the same case. It is probable that in most instances it has been mistaken for *P. aviculare* L., which it closely resembles in habit of growth and general aspect. Since recognizing it in Tippecanoe County I have been greatly surprised to find how abundantly it occurs. It would be well to examine herbarium specimens with some care for these two forms.

Generally speaking, the species of this genus can not be satisfactorily distinguished unless collected in fruit, a fact which seems to have been lost sight of in most of the herbarium sheets which have come to my notice.

GERANIACEÆ.

In this family, as at present limited, there are but the two genera *Geranium* and *Erodium*.

So far as I am able to determine the only species of geranium within our bounds are *G. Carolinianum* L. and *G. maculatum* L. Both seem of general distribution, although perhaps *maculatum* extends farther north and is everywhere much more abundant.

G. Robertianum L., reported from Dearborn County, by Dr. Collins, is probably *Carolinianum*. There is no apparent reason why *G. Robertianum* should not occur within the State, but as yet I have failed to find it in any collection. Several unpublished lists that have come into my hands have included *G. dissectum* L. The plants so referred are in every case depauperate forms of *G. Carolinianum* L.

Erodium cicutarium (L.) L'Her. is reported only from Gibson and Posey counties, by Dr. Schneck. It is to my mind very improbable that this rather rare, adventive plant, reported only from New York and Pennsylvania, should have found lodgement in these counties as a permanent member of our flora. Dr. Schneck preserved no specimens, but doubtful forms were passed upon by Dr. Gray. In my opinion the plant is not a member of the State flora, its admission in all probability being based upon a temporary escape. Unless additional data are at hand it will be dropped from the State list.

POLYGALACEÆ.

Eight species and one variety of the genus Polygala have been recorded in the State. Of these *Polygala Senega* L., *Polygala Senega latifolia* Torr. & Gray and *Polygala viridescens* L. (=*P.* sanguinia L.) are of general distribution and fairly abundant.

The following are reported from a single station:

P. ambigua Nutt. =(*P.* verticillata var. ambigua Wood), from Gibson and Posey counties, upon the authority of Dr. Schneck.

P. cruciata L., from Cass County, by Dr. Robert Hessler.

P. Nuttallii Torr. & Gray, from Jefferson County, by J. M. Coulter.

P. verticillata L. is reported from only two stations, Jefferson County and Noble County, while *P. polygama* Walt. is also reported but from two counties, Vigo and Elkhart. The difficulty of discriminating the species of this genus, because of their great variability and because of the fact that nearly related forms tend to become confluent, makes the inclusion of these forms reported from a single station a matter of some doubt. The material examined verifying the references has been so scant that critical study has been impossible. There is, however, in no instance any range improbability in the record. The well-known accuracy of the botanists reporting these forms is sufficient to justify their inclusion in the list. It is especially desirable that those in charge of herbaria should examine their Polygalas in the hope of both extending the range of these forms and justifying their inclusion in the State list.

VIOLACEÆ.

Sixteen species of the genus Viola have been recorded from the State, at least four of which seem questionable, so much so, indeed, that without additional evidence they should be excluded from the State list.

Viola hastata Michx., reported only from Clark County, upon the authority of Baird and Taylor, is a mountain form. It occurs in the Alleghanies in Pennsylvania and follows the system southward. It has an additional station in the extreme northeastern part of Ohio, but apart from this is confined to the mountain regions. It is closely allied to *V. pubescens*, Ait.,, from which it differs essentially in the size of the stipules. The halberd-shaped leaf often passing into an oblong to heart-shaped, while the broadly heart-shaped leaves of *pubescens* as frequently narrow.

The reference is undoubtedly incorrect, the plant being a narrow-leaved, rather glabrous form of the *V. pubescens* Ait.

V. primulaefolia L., reported as rare in moist soil in Gibson and Posey counties, by Dr. Schneck, I am forced to regard as a form of *V. blanda* Willd. *V. primulaefolia* is an eastern plant, ranging from New England to Florida near the coast. A glance at the descriptions of *blanda* and *primulaefolia* will serve to show how, with slight foliar changes, it might be possible to mistake the two forms. I have examined for intervening stations so far as I was able, but have found none that indicate even the slightest western movement of the species.

V. rostrata Pursh, reported from Jefferson County ("Clifty Ravine"), by C. R. Barnes, and from Noble County, by VanGorder is a rather rare northern form, extending southward along the Alleghanies. Of the two stations, that in Noble County would be the more probable. I have seen no specimen verifying either citation, but because of the known range of the form am inclined to refer it to a form of *V. striata* Ait. The most constant difference between *rostrata* and *striata* is in the spur. In the former it is slender and longer than the petals; in the latter it is thickish and shorter than the petals. It may, however, be a form of *V. Labradorica* Schrank (=V. canina var. Muhlenbergii Gray). I feel confident, however, that *V. rostrata* Pursh is not a member of the State flora.

Viola rotundifolia Michx., reported from Dearborn County, by Dr. Collins, and from Jefferson County, by Professor Young, is another eastern mountain form, whose presence in our territory is scarcely possible and certainly is very improbable. The recorded range of the plant reads: "Cold woods; Maine to Minnesota and southward along the Alleghanies." The form is so characteristic that it is difficult to understand with what species it may have been confused. The range probabilities, however, are so strongly against its presence in the State that in the absence of verifying specimens it must be excluded from the catalogue.

The admitted forms of the genus are as follows:

V. blanda Willd.

V. Canadensis L.

V. Labradorica Schrank (=V. canina var. Muhlenbergii Gray) a form not recorded north of Monroe County.

V. lanceolata L.

V. obliqua Hill (=V. palmata var. cucullata Gray).

V. palmata L.

V. pedata L.

V. pedatifida Don., reported from Wayne County, and also from Gibson and Posey. The form is western and is probably confined to the western tier of counties. The Wayne County reference is probably *V. pedata*.

V. pubescens Ait.

V. sagittata Ait., apparently confined to southern counties.

V. striata Ait.

V. tricolor L.

PLANTAGINACEÆ.

An examination of a large number of specimens from various localities referred to *Plantago major* L., showed the majority of them to be *P. Rugelii* Dec. The only character that readily separates the two forms is the number of seeds in the pod. In the case of *major*, running from eight to eighteen, and in *Rugelii* from four to nine. As the pods are of practically the same size, the difference in the size of the seeds is easily recognized. It is probable that in almost every region of the State *P. Rugelii* Dec. will be found in fair abundance closely associated with *P. major* L. The two forms run into each other in leaf, spike and bract characters, but may apparently always be separated by the number and size of seeds.

COMPOSITÆ.

Vernonia gigantea (Walt.) Brit., =(V. altissima Nutt.) is of much more general distribution than indicated in my Contribution to Flora of Indiana, IV, page 5. In the northwestern counties of the State it seems more abundant than *V. fasciculata* Michx., to which it is usually referred. In almost every collection thus far examined, *gigantea* is the prevailing form. I am inclined to believe it much more abundant in the State than *V. fasciculata* Michx.

As suggested in Contribution IV (supra), there are many reasons which lead to the belief that *gigantea* is really a hybrid and should be written *V. Noveboracensis* × *fasciculata*. Experiments are now under way for the determination of this point.

Through the courtesy of Dr. Eigenmann, I have received a list of plants of the northern lake regions of the State, which fairly represents

the flora of such restricted areas in the months of August and September. The list is herewith published in the form in which it was received, with thanks to Mr. Deam for the use of his notes. Comments upon some of the species are reserved for the forthcoming report upon the flora of the State.

A LIST OF PLANTS COLLECTED AT CEDAR, SHRINER AND ROUND LAKES.

BY C. C. DEAM, BLUFFTON.

The following species are represented in my herbarium by specimens collected by Mr. Williamson and myself. The number here recorded by no means represents the rich flora of the region.

Dryopteris Thelypteris (L.). A. Gray. September 2, 1897. Shriner Lake.

Typha latifolia L. September 2, 1897. Round Lake.

Potamogeton, four species. August 3, 1896. Shriner Lake.

Sagittaria rigida Pursh. August 6, 1896. Round Lake.

Panicum capillare L. August 6, 1896. Round Lake.

Panicum Crus-galli L. August 2, 1896. Round Lake.

Zizania aquatica L. August 6, 1896. Round Lake.

Homalocenchrus oryzoides (L.). Poll. September 2, 1897. Cedar Lake.

Muhlenbergia Mexicana (L.). Trin. September 2, 1897. Shriner Lake.

Cyperus Engelmanni Steud. September 1, 1897. Shriner Lake.

Cyperus rivularis Kunth. September 1, 1897. Round Lake.

Dulichium arundinaceum (L.). Britt. September 1, 1897. Round Lake.

Eleocharis interstincta (Vahl.). R. and S. September 1, 1897. Round Lake.

Eleocharis mutata (L.). R. and S. September 2, 1897. Round Lake.

Scirpus Americanus Pers. August 3, 1896. Shriner Lake.

Scirpus atrovirens Muhl. August 2, 1896. Shriner Lake.

Scirpus lacustris L. August 1, 1896. Shriner Lake.

Scirpus lineatus Michx. August 1, 1896. Shriner Lake.

Rynchospora glomerata (L.). Vahl. August 2, 1896. Round Lake.

Cladium mariscoides (Muhl.). Torr. September 2, 1897. Shriner Lake.

Carex comosa Boott. September 1, 1897. Shriner Lake.

Carex lupuliformis Sartwell. September 1, 1897. Shriner Lake.

Eriocaulon septangulare With. September 2, 1897. Round Lake.

Pontederia cordata L. August 1, 1896. Shriner Lake.

Juncus Canadensis J. Gay. September 2, 1897. Shriner Lake.

Pogonia trianthophora (Sw.). B. S. P. August 2, 1896. Shriner Lake.

Corallorhiza odontorhiza (Willd). Nutt. August 8, 1896. Round Lake.
Rumex verticillatus L. September 2, 1897. Cedar Lake.
Polygonum incarnatum Ell. August 6, 1896. Round Lake.
Polygonum punctatum Ell. September 2, 1897. Round Lake.
Polygonum sagittatum L. September 2, 1897. Cedar Lake.
Amaranthus blitoides S. Wats. September 2, 1897. Round Lake.
Silene stellata (L.) Ait. August 6, 1896. Round Lake.
Brasenia purpurea (Michx.). Casp. August 3, 1896. Shriner Lake.
Nymphæa advena Soland. August 6, 1896. Round Lake.
Castalia odorata (Dryand). Woodv. and Wood. August 3, 1896. Round Lake.
Actæa alba (L). Mill. August 3, 1896. Round Lake.
Hamamelis Virginiana L. August 1, 1896. Cedar Lake.
Spiræa salicifolia L. August 4, 1896. Cedar Lake.
Cassia Marylandica L. August 1, 1896. Round Lake.
Meibomia Dillenii (Darl.) Kuntze. September 1, 1897. Round Lake.
Meibomia Michauxii Vail. September 1, 1897. Round Lake.
Meibomia nudiflora (L.). Kuntze. July 30, 1896. Round Lake.
Lespedeza frutescens (L.). Britton. September 1, 1897. Round Lake.
Lespedeza Virginica (L.). Britton. September 1, 1897. Round Lake.
Euphorbia corollata L. September 3, 1897. Cedar Lake.
Celastrus scandens L. August 1, 1896. Round Lake.
Impatiens aurea Muhl. July 29, 1896. Shriner Lake.
Decodon verticillatus (L.). Ell. August 6, 1896. Round Lake.
Myriophyllum, one species. August 3, 1896. Round Lake.
Cicuta bulbifera L. September 2, 1897. Round Lake.
Cicuta maculata L. August 3, 1896. Round Lake.
Scutellaria galericulata L. August 2, 1896. Round Lake.
Scutellaria laterifolia L. September 3, 1897. Round Lake.
Monarda fistulosa L. August 4, 1896. Round Lake.
Lycopus rubellus Moench. September 1, 1897. Shriner Lake.
Mentha piperita L. July 31, 1896. Round Lake.
Gerardia paupercula (A. Gray). Britton. September 1, 1897. Shriner Lake.
Utricularia resupinata B. D. Greene. September 2, 1897. Round Lake.
Utricularia vulgare L. June 24, 1898. Shriner Lake.
Cephalanthus occidentalis L. August 3, 1896. Shriner Lake.
Lobelia cardinalis L. July 31, 1896. Round Lake.
Lactuca villosa Jacq. September 2, 1897. Cedar Lake.
Hieracium scabrum Michx. September 1, 1897. Round Lake.

Eupatorium purpureum L. July 31, 1896. Round Lake.
Solidago, one species. August 6, 1896. Cedar Lake.
Euthamia graminifolia (L.). Nutt. August 1, 1896. Cedar Lake.
Aster macrophyllus L. August 6, 1896. Round Lake.
Inula Helenium L. August 6, 1896. Round Lake.
Silphium trifoliatum L. July 31, 1896. Round Lake.
Rudbeckia laciniata L. September 2, 1897. Cedar Lake.
Bidens Beckii Torr. August 6, 1896. Round Lake.
Bidens trichosperma (Michx.). Britt. August 6, 1896. Round Lake.
Erechtites hieracifolia (L.). Raf. September 2, 1897. Cedar Lake.
Carduus muticus (Michx.). Pers. September 2, 1897. Cedar Lake.

Some Unrecognized Forms of Native Trees.

By Stanley Coulter.

In the case of certain of our familiar forests there is a popular or commercial recognition of certain well-marked forms which have either escaped the attention of botanists or have been considered of such slight importance as to receive no mention in descriptive works. Some of these forms are so distinct and so persistent as to raise the question as to whether they may not be entitled to varietal rank. Certainly in a study of our forest flora they must be taken into account. I desire in this paper to call atention to some of these botanically unrecognized forms, hoping by this means to receive added information upon this point.

ASIMINA TRILOBA DUNAL.

The papaw has two easily distinguishable forms, which may be characterized as—

1. A large-fruited form, becoming a rich yellow upon ripening.
2. A small-fruited form, remaining white upon ripening.

Among the evident fruit differences the following are to be noted. In the large-fruited form the pulp is much softer and more yielding than in the small-fruited form; it possesses a much stronger flavor and odor; the

seeds are less numerous, although somewhat larger. The color of the outer skin changes to black under the action of frost, while in the small-fruited type it remains green. Form 1 furnishes the really edible fruit. The larger form is also in cross section, almost circular, while the small-fruited form is elliptical, being compressed dorso-ventrally.

In habit, form 1 is the taller plant, the branches are more appressed, and the bark is a decided brown. In form 2, the branches are spreading and the bark much lighter in color, being gray rather than brown.

The inner bark of form 1, after maceration in water, is used in making rough ropes and withes; that of number 2 can not be so used, being much more brittle, or rather of much less tensile strength.

As compared with form 2, the leaves of form 1 are larger, more acute, a deeper green and much more highly odorous. The leaves of the papaw are popularly supposed to possess preservative properties and are used to cover meat, dressed poultry and fish, butter, etc. For this purpose only the leaves of form 1 are used. Large areas of the other forms will be passed over in the search for the highly odorous leaves of the large-fruited form. In histological features, the leaves of the two forms differ chiefly in the palisade layer and the relative thickness of the outer walls of the epidermis. This later, in form 2, being from two to four times thicker than in its larger leaved relative.

The date of flowering differs slightly, form 2 opening its smaller, less deeply colored flowers from a week to ten days later than form 1.

In our area form 2 has much the wider soil range. While always associated with form 1, it also thrives in a much thinner, lighter soil and in drier situations. When growing together, the two forms are easily separable, never by any chance becoming confluent.

While not of the opinion that these differences are sufficient to create a new species, I am inclined to think that in our area form 2 should have recognition as a distinct form, and suggest that it be known as *alba*.

JUGLANS NIGRA L.—Black Walnut.

Of this familiar tree there exists in Indiana two if not three easily separable forms:

1. Fruit spherical, nut following shape of hull; hull thick, bright green in immature state, turning black upon ripening; pulp becoming

black and very soft under the action of frost; kernel very oily, of somewhat rank flavor.

2. Fruit ovoid, much smaller than in number 1. Nut following shape of hull; hull relatively thin, bright green in immature state, turning yellow upon ripening or under the influence of frost; pulp drying up and hardening at maturation; kernel dry (not markedly oily), and of an agreeable flavor. This is the form which the wood-wise boy gathers for his winter supply.

The leaf of form 2 is much smaller than that of form 1, the leaflets being smaller, more sharply acute and finely serrate; they are also much less vividly green than those of form 1, a difference in color that seems due to the thicker epidermis.

Form number 2 grows in drier situations than form 1, though occasionally extending into the regions of the latter. In these cases there seems to be no blending of forms. The two forms are sharply distinct wherever associated.

Lumbermen assert that the wood of form 2 is much lighter in color and of much less commercial value than that of form 1. Whether or not there is difference in the period of flowering and maturation of fruit I am unable to state. Form 1 is that of ordinary descriptive botanists. form 2 not being noted or indicated. In our area it is of general occurrence and is known by the boys as the "little black walnut."

Form 3, so far as I know, is found only in a few localities near Lafayette. The fruit closely resembles the English walnut in some particulars, while in others it resembles the butternut. The hull is thin and without appreciable pulp at any season. The shell is very thin, the nut cracking as easily as the English walnut. The kernel is not at all oily and is very sweet. Some few trees are found upon the west bank of the Wabash River near Lafayette, and a few others near the Purdue campus. This form I described before the Academy of Science in 1890 under the title of "*An Aberrant Form of Juglans nigra.*" In that paper I suggested the fruit peculiarity was due to an early defoliation of the trees which occurred that year. Observations continued from that time until the present convince me that the opinion there expressed is not borne out by facts. The form has maintained itself in the stations indicated through these years from 1890 to 1900, its fruit always presenting the features given above. Dr. Schneck suggests that it is a hybrid of *J. cinerea* × *J. regia* in which he follows J. Robinson in "Our Trees" (published by the Essex

Institute), in which a similar form is recorded. I am inclined to doubt the fact of the hybrid nature of the form for reasons that need not be considered in this connection. Whatever the origin of the form, it is definitely established in the two stations indicated. I hope during the coming season, in the case of both the papaw and walnuts, to discover whether or not these variations show a tendency to a "place mode."

LIRIODENDRON TULIPIFERA L.—Tulip Tree. Yellow Poplar. White Poplar.

Lumbermen distinguish between "yellow poplar" and "white poplar," a difference based upon the color of the wood. So far as I am able to judge, this difference is dependent upon the age of the tree and the soil conditions, being associated with no structural differences. In my opinion, it will be found that trees of this species, growing in tenacious clay soils, have the denser structure and darker color characterizing the yellow poplar, while in light, dry soils and loam, the white poplar is found. In both conditions the wood of the older trees is of a darker color, in some cases approaching brown. I hope that a series of observations now in progress will make it possible to determine the relation between the soil character and these alleged commercial varieties. If there is any method by which the two forms are to be distinguished by flower, fruit, leaf or bark characters, it has escaped my attention.

DIOSPYROS VIRGINIANA L.—Persimmon.

This tree shows at least two, perhaps three, sharply distinct forms existing in the same area without becoming confluent. A discussion of these differences is unnecessary since in "*The American Persimmon,*" Bulletin No. 60, Vol. VII, of the Agricultural Experiment Station of Purdue University, Messrs. Troop and Hadley discuss these variations fully. I quote a few sentences from this bulletin:

"They differ in quality as much as our cultivated apples. Some are very astringent, others are insipid and worthless, still others are sweet and delicious.

"The fruit differs in size from that of a small wild plum to an inch and one-half or two inches in diameter. They also vary greatly in form;

some are globular, others either conical or oblong, those of the globular form predominating."

The wide soil range of the persimmon indicates that these differences may be dependent upon soil character, at least in large measure. A warm soil well exposed to the sun is best adapted to the persimmon, but it is found on almost any kind of soil from rich bottom land to the thin soil of hill tops. In Lawrence and Orange counties, according to Messrs. Troop and Hadley, it is found in great luxuriance in red clay soil areas, in lands exhausted by persistent cropping and which had been abandoned as worthless.

In this wide range of soil conditions it would seem possible to determine with some accuracy the effect of soil character upon this species.

I have called attention to these variations chiefly as an intimation that our forest flora is much less perfectly known than its importance merits, and in the hope that it will direct attention to the range of variation in these and other species.

Seedlings of Certain Native Herbaceous Plants.

By Stanley Coulter and Herman B. Dorner.

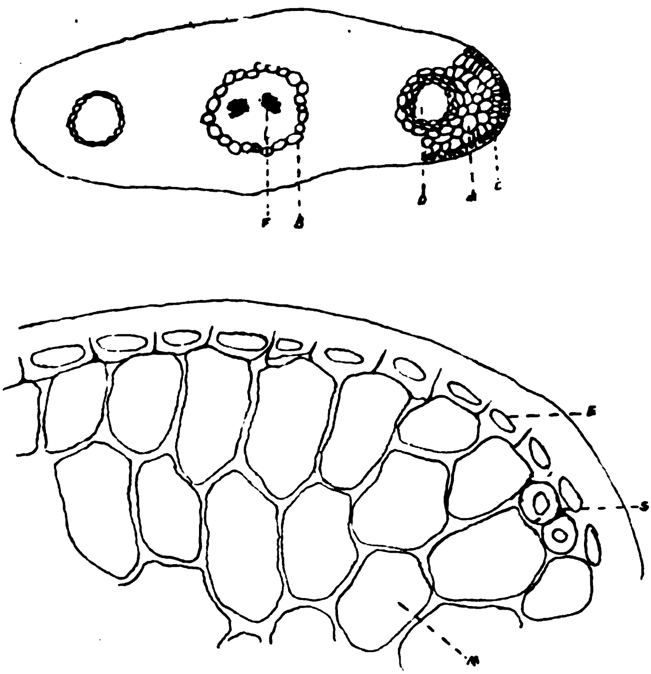
The Resin Ducts and Strengthening Cells of Abies and Picea.

By Herman B. Dorner.

Of recent years great strides have been made in systematic botany, especially in the line of adding new determinative features to classification. At the present time not only external features, but also internal structures are used for the determination of generæ and species. This system of classification, according to internal structure, has best been carried out in the genus Pinus.

The first work done upon the pines with the internal structure in view,

was done by F. Thomas in 1865. Further study was made upon the subject by C. E. Bertrand in 1871-74 and W. B. McNab in 1875-77. However, the first man to study the subject closely was the late Dr. George Engelmann, whose name is more intimately associated with the conifers than that of any other man. His first work along this line was his "Synopsis of American Firs," which was published in 1878 in the Trans. St. Louis



ABIES BALSAMEA.

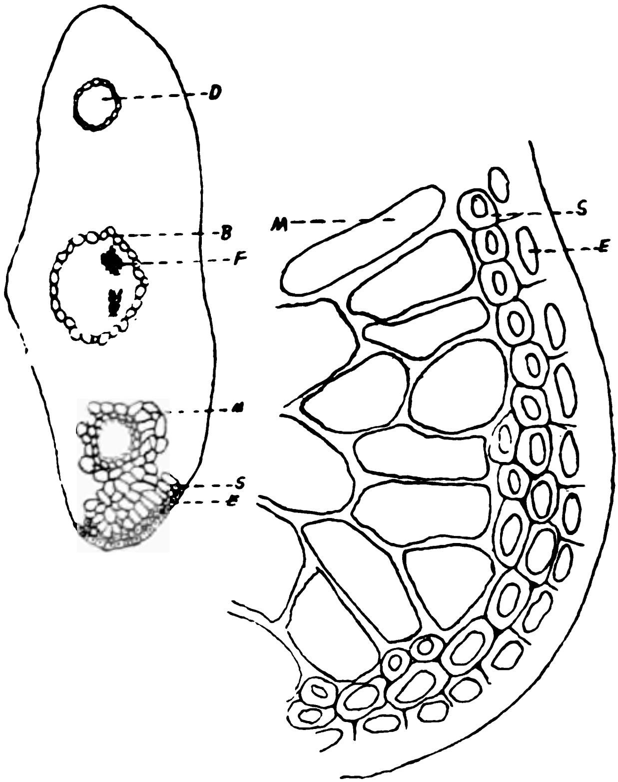
D Ducts.	M Mesophyll.
B Bundle sheath.	E Epidermis.
F Fibro-vas. bundle.	S Strength. cells.

Acad. III, pp. 593-602. In 1880 there appeared in the same journal, IV, pp. 161-189, his "Revision of the Genus Pinus." However, in the second paper he merely used the internal structure to distinguish between the different subdivisions of the genus.

It is at this point that J. M. Coulter and J. N. Rose took up the work. Their idea was to apply the characters obtained not only to the subdi-

visions but to the species as well. The results of this work appeared in 1886 in the "Botanical Gazette," XI, pp. 256-262 and 302-309.

The object of their study was to determine whether the pines could be separated from one another by means of the structure of the foliage



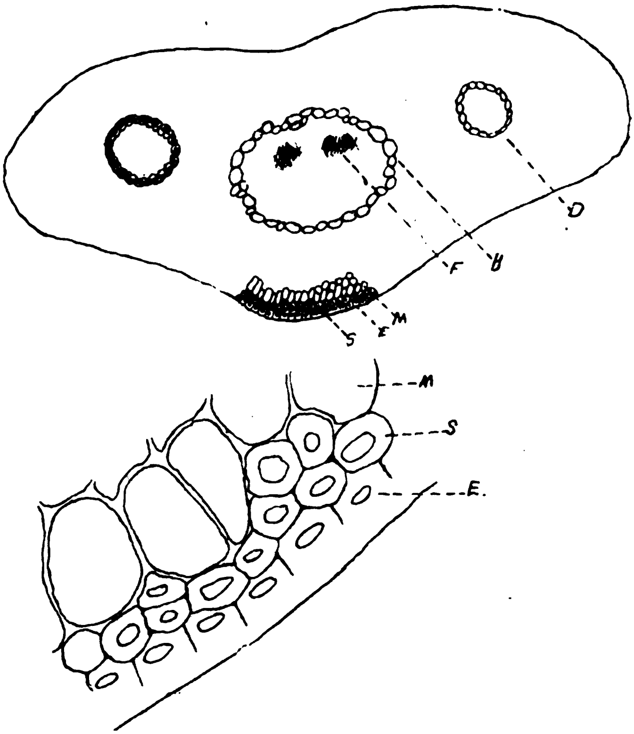
ABIES FRASERI.

D	Ducts.	M	Mesophyll.
B	Bundle sheath.	S	Strength. cells.
F	Fibro-vas. bundle.	E	Epidermis.

leaf. The material used by them was gathered from as large a range as possible and thus have the material grown under as many conditions as possible. Their determinative features were based upon the number of fibro-vascular bundles, the position and kind of strengthening cells, the position of the stomata, the number and position of the ducts, thickness

of the walls of the bundle sheath, and the number of leaves in a fasicle. With these characters, which appeared to be permanent ones, a system of classification was formulated which was very useful in connection with the classification based upon external features.

Since this time comparatively little, if any, work has been done upon



ABIES SUBALPINA.

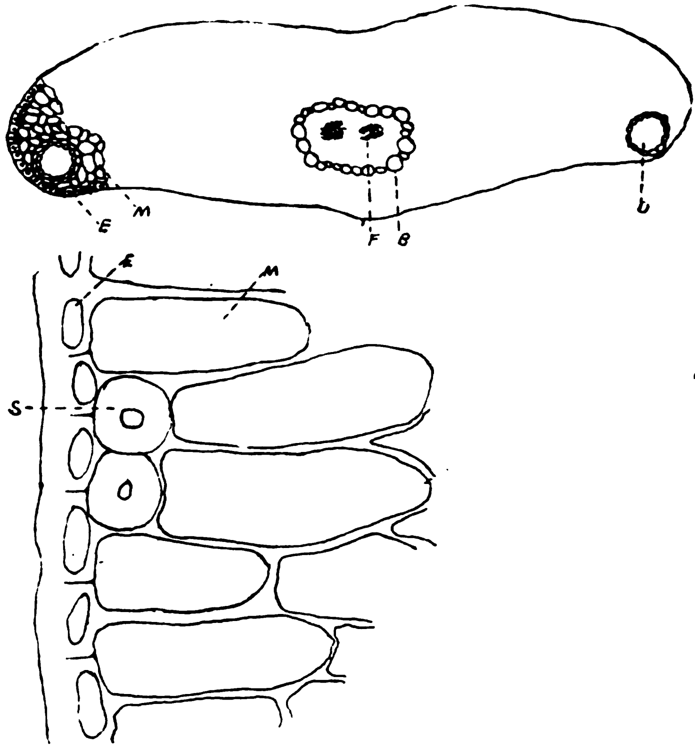
D	Ducts.	M	Mesophyll.
B	Bundle sheath.	E	Epidermis.
F	Fibro-vas. bundle.	S	Strength. cells.

the Coniferae in this line. It was with this same end in view that the study of the generæ Abies and Picea was taken up. The object here, as in the case of the Pinus, was to work out the characteristic features of the species of the two generæ and find their determinative value.

The material used was obtained of C. S. Sargent of the Arnold Ar-

boretum, and comprised only truly American species. The collection consisted of six species of Abies and five of Picea, all of the United States.

In preparing the leaves for study, transverse sections were made through the center of the leaf so as to avoid the danger of getting sections without the characteristic number of ducts or fibro-vascular bundles. Al-



ABIES GRANDIS.

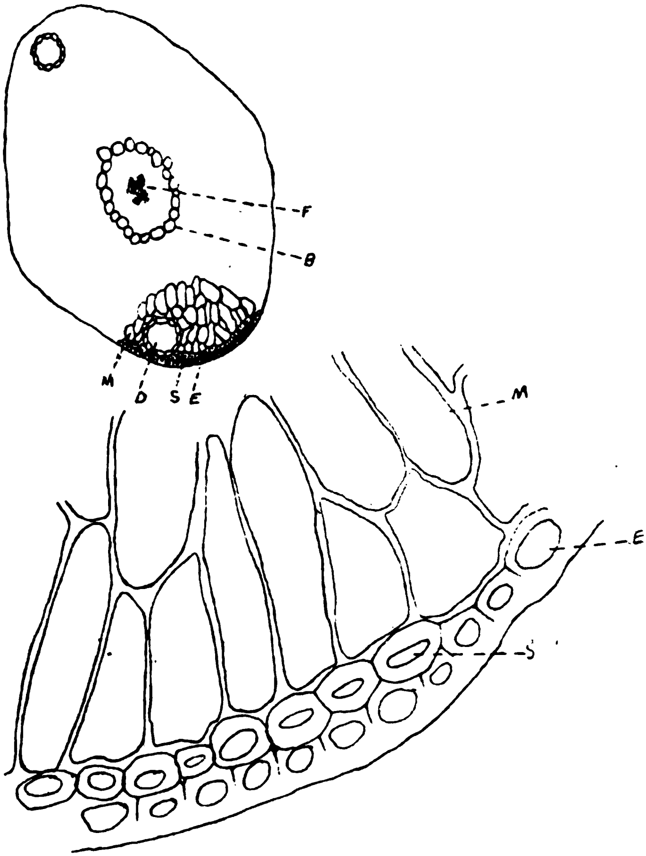
D	Ducts.	M	Mesophyll.
B	Bundle sheath.	E	Epidermis.
F	Fibro-vas. bundle.	S	Strength. cells.

together, between five and six hundred specimens were studied. In this determination only features represented in these transverse sections were used.

In the genus Abies the leaf structure is essentially the same as that of the genus Pinus. The leaf, as a whole, is divided into three parts, the

cortical, or outer part, the *mesophyll*, or chlorophyll-bearing part, and the *fibro-vascular* region surrounded by its bundle sheath.

The *cortical* region is composed of an epidermis and a series of strengthening cells lying directly beneath. The epidermis is composed of

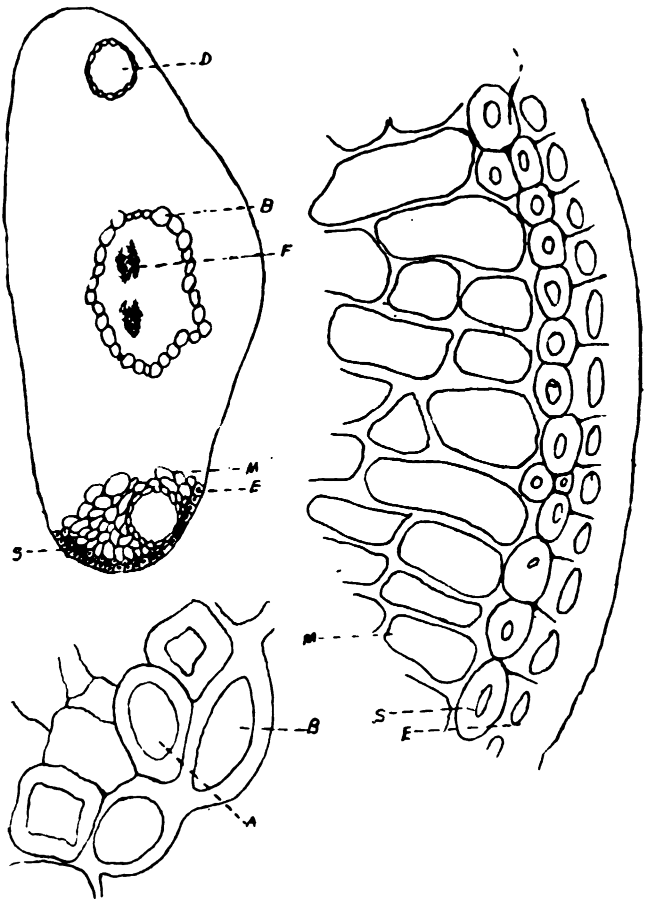


ABIES MAGNIFICA.

D Ducts.	M Mesophyll.
F Fibro-vas. bundle.	E Epidermis.
B Bundle sheath.	S Strength. cells.

a single layer of thick-walled cells with a cuticle twice as thick as the lumen of the cell. This epidermis is broken by the openings of the stomata. These stomata are arranged in rows down the sides of the leaf

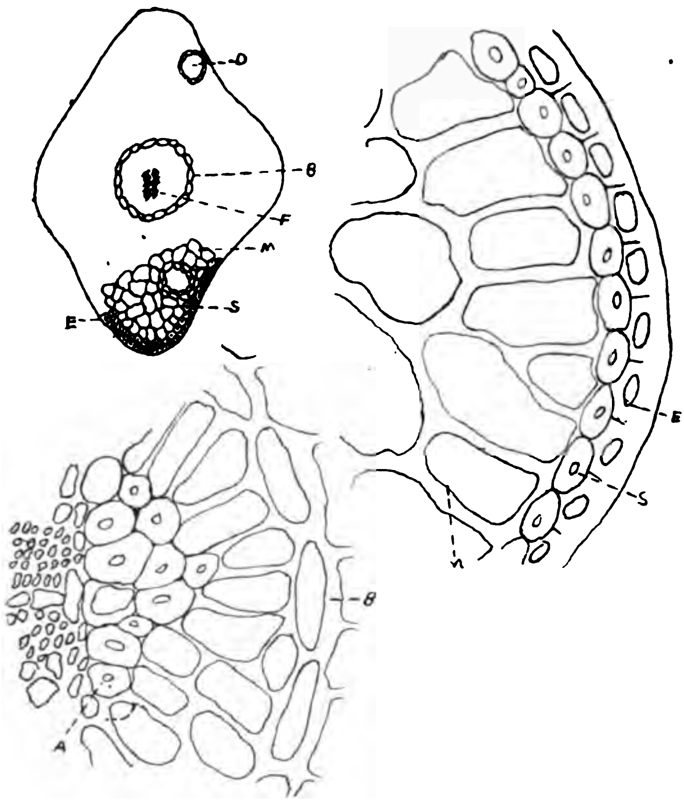
in the hollows between the angles. The strengthening cells are all thick walled and without content. For convenience these cells will be referred to as thin and thick walled but the terms are mere relative ones. The term strengthening cell, as here used, refers to these thick-walled cells wherever found.



ABIES CONCOLOR.

D Ducts.
B Bundle sheath.
F Fibro-vas. bundles.
M Mesophyll.
E Epidermis.
S Strength. cells.
A Strength. cells within sheath.

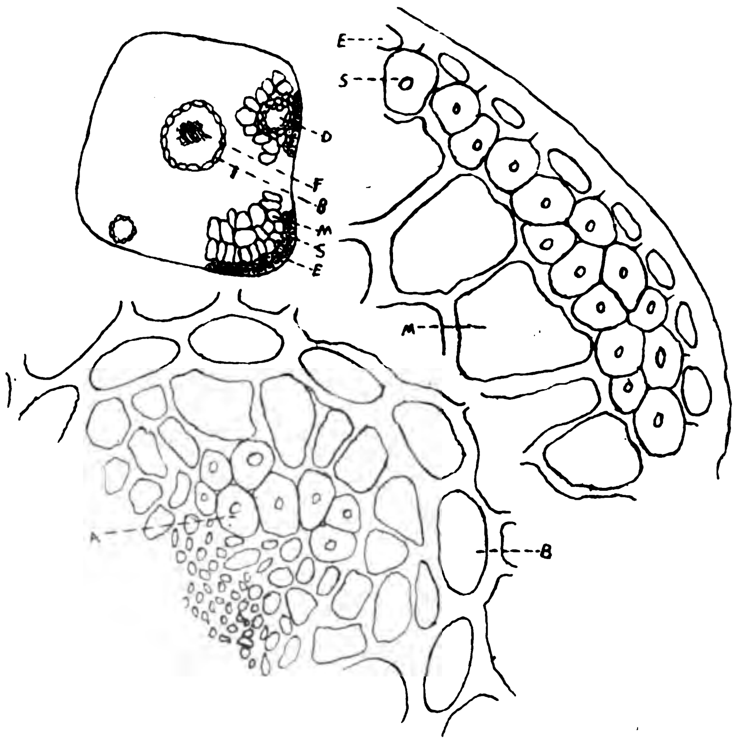
The *mesophyll* region is composed of chlorophyll-bearing, parenchyma cells. These cells differ from the corresponding ones of the pine, in that they do not show that characteristic infolding of the cell wall. The cell walls are smooth, more like the parenchyma of an ordinary leaf. It is within this region that the resin ducts occur. These ducts may be either *peripheral* when they lie directly under the epidermis, or *medial* when they lie entirely surrounded by the parenchyma. These lie parallel to the longer axis of the leaf and are surrounded by a series of strengthening cells. Lining the inside of the duct is a single layer of secretory cells.



PICEA MARIANA.

D Ducts. M Mesophyll.
B Bundle sheath. S Strength. cells.
F Fibro-vas. bundles. E Epidermis.
A Strength. cells within sheath.

The *fibro-vascular* region lies in the center of the leaf and is surrounded by a somewhat imperfect bundle sheath. The sheath is composed of large and small cells intermingled. In the center lie the fibro-vascular bundles, which are two in number, with the exception of Abies magnifica, where the two seem to have merged into one. Strengthening cells sometimes appear within the bundle sheath and seem to be a constant feature in the species in which they occur.



PICEA RUBRA.

D Ducts. E Epidermis.
S Strength. cells. M Mesophyll.
F Fibro-vas. bundle. B Bundle sheath.
A Strength. cells within sheath.

From the characteristics above mentioned the following synoptical arrangement of the genus has been arranged.

*Ducts medial.

†Strengthening cells absent or few in number.

1. *Abies balsamea* (L.) Mill. Strengthening cells few in number or entirely absent, thin walled.

††Strengthening cells always present in considerable numbers.

2. *Abies Fraseri* (Pursh.) Lindl. Strengthening cells in a continuous layer within the epidermis, sometimes doubling at the angles, especially the dorsal angles. Cells thin walled..

3. *Abies subalpina*, Engelmann. Strengthening cells mostly in the angles; in a single layer in the lateral angles and a double or triple row in dorsal angle, also occurring in groups between the angles.

**Ducts peripheral.

†Strengthening cells few in number, occurring singly or in groups.

4. *Abies grandis*, Lindley. Strengthening cells occurring singly or in groups of from two to five, thick walled, sometimes occur within bundle sheath.

††Strengthening cells abundant in angles of the leaf in single or double rows.

5. *Abies magnifica*, Murray. Strengthening cells thick walled. The two vascular bundles merged into one.

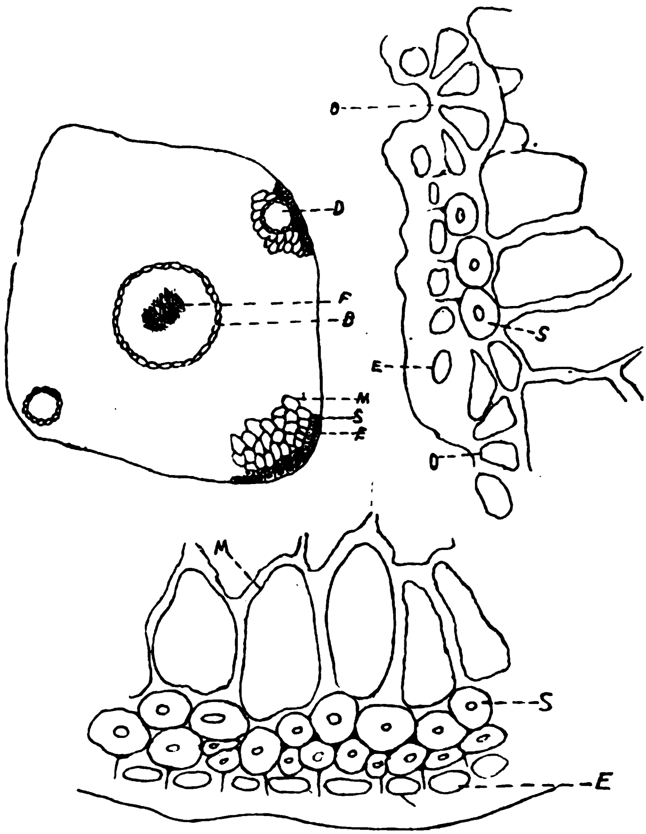
6. *Abies concolor*, Lindley and Gordon. Strengthening cells very thick walled, some present within the bundle sheath.

The structure of the leaf of the Picea is about the same as that of the Abies. The leaf, however, is of a different shape. In the cross section the Abies show a lateral axis very much longer than the dorsi-ventral axis. In the Picea the two axes are about equal. There are also other characteristic differences. The leaf, as in the Abies, is divided into *cortical*, *mesophyll* and *fibro-vascular* regions.

The *cortical* region. The epidermis is composed of thick-walled cells as in the Abies. The strengthening cells are arranged about the entire leaf, and like the epidermis, this layer is interrupted only by the stomata. The stomata here are also arranged in rows along the side of the leaf. Between the openings of the stomata the strengthening cells are much thinner walled than in the remainder of the leaf.

The *mesophyll* region is composed of wavy-margined, chlorophyll-bear-

ing, parenchyma cells. This region also contains the ducts, which vary from none to two in number. It appears as if the number of ducts should be two, if the leaf be bi-laterally symmetrical. However, in Picea Canadensis never more than one duct was found in a single leaf. Dissatisfied



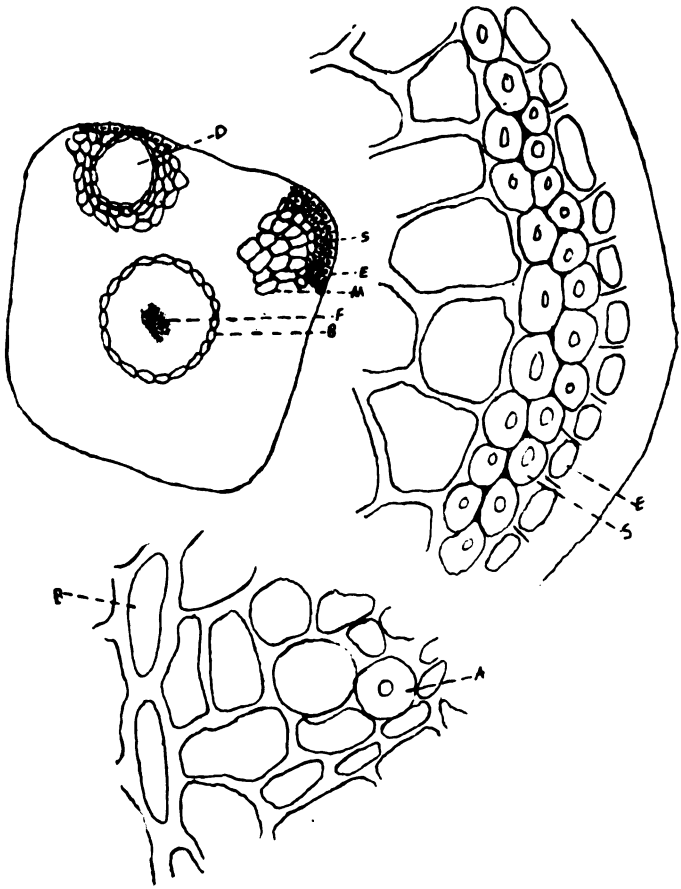
PICEA PUNGENS.

D Ducts. E Epidermis.
S Strength. cells. M Mesophyll.
F Fibro-vas. bundle. B Bundle sheath.
O Stomata.

with this variation of the number of ducts, sections were made through the entire leaf. From these sections it was found that the duct did not extend the entire length of the leaf, but was somewhat spindle-shaped,

with the widest part in the center of the leaf and then gradually tapering to either end. This accounts, then, for the variation of the number of ducts. The ducts are all peripheral and are surrounded by a single layer of strengthening cells and lined by a layer of secretory cells.

The *fibro-vascular* region lies in the center of the leaf and is surrounded



PICEA ENGELMANNI.

D Ducts. E Epidermis.
S Strength. cells. M Mesophyll.
F Fibro-vas. bundle. B Bundle sheath.
A Strength cell within sheath.

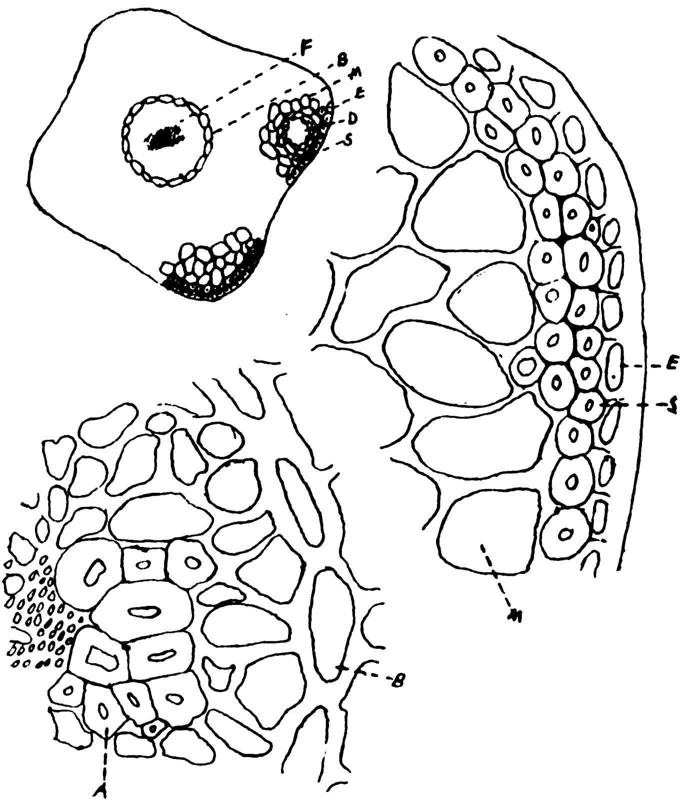
by a very regular bundle sheath. In all five species only one *fibro-vascular* bundle is present. Strengthening cells may or may not be present in this region, but when present are good determinative features.

From the data secured from the study of the Picea, the following arrangement has been made:

*Ducts always *two.*

†Lateral axis much longer than dorsi-ventral axis.

1. *Picea Mariana* (Mill.) B. S. P. Strengthening cells in a single row, very thick walled, some occur within bundle sheath.



PICEA CANADENSIS (Alba).

D Ducts.	M Mesophyll.
S Strength. cells.	E Epidermis.
F Fibro-vas. bundle.	B Bundle sheath.

A Strength. cells within sheath.

†Lateral axis and dorsi-ventral axis about equal.

2. *Picea rubra* (Lamb.) Link. Strengthening cells very thick walled, occurring in a single row, sometimes doubled or tripled at the angles. Some strengthening cells occur within the sheath.

**Ducts *none* to *two*.

3. *Picea pungens* Engelmann. Strengthening cells thick walled, some thick-walled cells occurring singly or in groups between the stomata, with tendency to double row at the angles.

4. *Picea Engelmanni* Engelmann. Strengthening cells in a single row, sometimes doubled at the angles; thick walled. A single cell sometimes occurs within the bundle sheath.

***Ducts *none* to *one*.

5. *Picea Canadensis* (Will.) B. S. P. (=Picea alba Link.). Strengthening cells in a single row sometimes doubled at the angles; very thick walled; some occur within bundle sheath.

Although the above synoptical arrangements appear to be conclusive within themselves they are valuable only in conjunction with the external features.

A Proteolytic Enzyme of Yeast.

By Katherine E. Golden.

INTRODUCTION.

The enzymes are auxiliary substances which are formed where solid bodies are to be liquefied. They are peculiar in that they decompose complex substances without being affected themselves in any way by the action, and also that even in minute quantities they can produce very marked results. They are important in animal and plant metabolism and occur both in the cells and in solution in secretions of the cells. In the case of unicellular organisms, the metabolic processes are carried on throughout their entire substance, the food substance being absorbed into the cell, where the enzyme is formed and does its work. This, however, is not always the case, the enzyme sometimes being excreted, the work of absorption following its action. This latter process is peculiar to multicellular organisms, having certain parts differentiated for special work,

the enzymes being formed in one set of cells, and excreted into the parts where the absorption of food takes place.

The composition of the enzymes is not known, some inclining to the view that they are of a proteid nature, while others think that they are nucleo-proteid, but as yet it is not definitely settled, as the enzymes have not been obtained in a pure condition, their reactions being connected with those of the substances with which they are associated. On account of this lack of knowledge as to their composition the enzymes have been classified according to the substances which they decompose.

The proteolytic enzymes are those which decompose proteids into less complex substances. There are two classes of these, the peptic and tryptic enzymes. The peptic enzymes decompose proteids to peptones, while the tryptic enzymes go farther, effecting the decomposition of the peptones to amides. In plants the amides are formed as antecedents to proteids, helping in the reconstruction of proteids as well as aiding in their osmosis by decomposition. When the carbohydrate, which was united with the amide, forming the proteid, is used up, the amide unites with a fresh carbohydrate, again forming a proteid. The enzyme in the plant, which causes this decomposition, is often in such minute quantity that it is almost impossible to determine its presence.*

Only a very few of the vegetable proteolytic enzymes have been investigated, and nearly all of these are from the higher plants. Those which have been investigated minutely have been found to be of a tryptic nature. A few of the fungi have also been found to secrete a proteolytic enzyme among these yeast.[1] It is claimed that if yeast be deprived of both oxygen and food material that it breaks up its own reserve proteid, and also, that if yeast be pressed, and the extract collected and heated to 45° C., a bulky coagulum is formed, which disappears in a few days, the extract in the meantime being kept under antiseptic conditions. The digestion of the reserve proteid and the disappearance of the coagulum indicate the presence of a proteolytic enzyme.

Proteolysis by yeasts has been noted but indirectly, except in the case of the pressing from the yeast of an extract by Büchner.[2] Jörgensen,[3] in describing S. Jörgensenii and S. membranæfaciens states that the

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* Kerner and Oliver. Natural History of Plants. Vol. I, part 2.

[1] Green, J. R. The Soluble Ferments and Fermentation, 1899, pp. 215–217.

[2] Büchner, E. Ber. d. deut. chem. Gesell., 1897.

[3] Jörgensen, A. Micro organisms and Fermentation, 1893.

yeasts cause a slow liquefaction of wort gelatine; and Frankland,[4] in his description of S. liquefaciens, states that it liquefies gelatine fairly rapidly. This action of the three yeasts indicates the excretion of proteolytic enzymes.

Though the statement relative to the extraction of a proteolytic enzyme from yeast is made of pressed yeast, no particular species being named, and there are various pressed yeasts, yet only in the three cases cited has the direct liquefaction of gelatine been noted.

EXPERIMENTS.

Among some wort gelatine yeast cultures I found one which had liquefied the gelatine. On examining the culture it proved to be contaminated by another yeast from the air. The yeasts were separated, and when grown apart, the "wild" yeast was found to be the one which caused the liquefaction. Cultures were made into both the ordinary beef broth gelatine and wort gelatine[5] to determine the constancy of this characteristic of the yeast. Tube and plate cultures of both kinds of gelatine showed liquefaction, the wort gelatine, however, being liquefied sooner than the beef gelatine. From thirty to forty days were required to liquefy a tube containing 6 cc. wort gelatine. The liquefaction was not uniform, even when conditions of media and temperature were alike. Wort gelatine plate cultures became liquefied in about two weeks. These results show undoubtedly the excretion of a proteolytic enzyme by the yeast.

Investigations conducted by Fermi[6] have shown that antiseptics in small amounts are not injurious to enzymes. This property is taken advantage of in the testing for enzymes, and also in determining, relatively, their strength. Water is saturated with thymol to which 5 per cent. of gelatine is added, then placed on a water bath until the gelatine is dissolved, after which 10 cc. are placed in tubes. These are ready for use as soon as the gelatine sets.[7]

To test the strength of the enzyme produced by the yeast, I obtained extracts by filtering the liquefied gelatine from tube cultures. In the first experiment 3 cc. of the extract were used in each tube of thymol gelatine

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[4] Saccardo, P. A. Sylloge Fungorum, Vol. VIII, pp. 916-922.
[5] Wort to which is added 7% gelatine. The wort had .23% acid, estimated as lactic.
[6] Lafar, F. Technical Mycology, Vol. I, 1898, p. 300.
[7] Same as ref. 6.

and a small amount of thymol added to the extract to prevent any further development of the yeast. The liquefaction of the thymol gelatine did not run quite uniformly: In twenty-five days one tube had 8 cc. gelatine liquefied, another had 7½ cc., while a third had 7¼ cc. A second set having extract from cultures six weeks old, in ten days, one liquefied 2 cc. gelatine, a second one 2.2 cc., and a third one 2.5 cc.

Wort in which yeast had been grown for ten days was filtered and 3 cc. of the filtrate used in thymol gelatine tubes, but this was very weak in enzyme. In ten days a cup-shaped depression was formed in the top of the gelatine, but no further action could be discerned. Both the wort gelatine and wort extracts were turbid when placed in the thymol gelatine. It required eight days for the wort extract to become clear and ten days for the wort gelatine extract.

As has been said already, the proteolytic enzymes are of two kinds, the peptic and the tryptic, the pepsin of the gastric juice and the trypsin of the pancreatic juice being taken as types. Besides differing in their decomposition products, they differ in other respects. Pepsin can act only in the presence of dilute acid and is injured by the presence of even a small quantity of the alkaline salt, Na_2CO_3, which is most favorable to the action of trypsin. Trypsin can also act in neutral or slightly acid solutions. A neutral salt in solution is deleterious to both enzymes, but especially so to pepsin, though according to Edkins[8] trypsin is aided by the presence of from 1 to 2 per cent. NaCl, though greatly retarded by 8 per cent. The vegetable trypsins which have been investigated are most active in faintly acid solutions.

In determining the kind of ferment, whether of a peptic or tryptic nature, the thymol gelatine was used for control, and the thymol gelatine with 1 per cent. NaCl, and 1 per cent. Na_2CO_3 added. Tubes of egg albumen were also used.

The following table shows the result of the experiment:

[8] Green, J. R. Fermentation, 1899, p. 193.

S. LIQUEFACIENS EXTRACT.

Experiment.	Age of Culture.	No. cc. Extract.	Time of Clearing.	Time of Liquefaction.	No. cc. Gelatine Lique.
Thymol gelatine	52 days.	2.5	6 days.	17 days.	5.50
Thymol gelatine + 1% NaCl	52 days.	2.5	3 days.	17 days.	6.00
Thymol gelatine + 1% Na_2CO_3	52 days.	2.5	4 days.	17 days.	2.70
Thymol gelatine	50 days.	1.5	1½ days.	17 days.	4.50
Thymol gelatine + 1% NaCl	50 days.	1.5	5 days.	17 days.	4.75
Thymol gelatine + 1% Na_2CO_3	50 days.	1.5	3 days.	17 days.	1.50
Thymol gelatine	40 days.	1.5	4 days.	17 days.	5 00
Thymol gelatine + 1% NaCl	40 days.	1.5	3 days.	17 days.	7.00
Thymol gelatine + 1% Na_2CO_3	40 days.	1.5	2 days.	17 days.	1.75
Egg albumen	52 days.	2.5	6 days.	17 days.	1.00
Egg albumen	50 days.	1.5	8 days.	17 days.	Cup-shaped depression.

Average—T. g., 5.00; T. g. + 1% NaCl, 5.92; T. g. + 1% Na_2CO_3, 1.98.

As indicated in the table, the presence of Na_2CO_3 seems to aid in the enzymic action, as the liquefaction was greater in each case when this was present than in the tubes without any salt. The extract in all the tubes, with the exception of that containing Na_2CO_3 gave a slightly acid reaction. The Na_2CO_3 seemed to hinder the action somewhat, as that was so much lower than either of the others.

In the work of Hahn,[9] and of Hahn and Geret,[10] it would seem as if they draw conclusions in regard to the presence of proteolytic enzymes in pressed yeast from somewhat indefinite causes. In the one case Hahn used pressed yeast, mixing it with *kieselguhr* and squeezing from it a liquid in the same manner as Büchner extracted his zymase. This liquid was treated with chloroform, to which was added gelatine and a trace of phenol. The extract liquefied the gelatine. Then Hahn and Geret used extract obtained in the same way with chloroform alone, keeping the solution at 37° C. for several weeks. The chloroform served to precipitate the proteids and keep the solution free from living organisms. A bulky precipitate was formed, which gradually disappeared. The liquid again became turbid, the second turbidity being due to the formation of amido compounds (tyrosin and leucin). From these experiments they conclude that they have extracted a proteolytic enzyme from the yeast. If the pressed yeast consisted of yeast only, there would be no question in regard to the results, but pressed yeast always contains a relatively large number of bacteria and a few moulds. Among the bacteria one is pretty sure to find some liquefiers.

To test for the presence of liquefiers I made some gelatine plate cultures from pressed yeast; and a description of one which contained only one colony of a liquefying bacterium will serve to indicate the power of the enzyme which was excreted. When the liquefying colony was first noted it was ½ mm. in diameter but at the end of twelve hours it had liquefied a spot 19 mm. in diameter; in twenty-three hours the spot had increased to forty-seven mm. in diameter and in forty-eight hours the gelatine of the entire plate was liquefied. Cultures were made into beef gelatine and the gelatine (6 cc.) was liquefied in forty-eight hours. The liquefied gelatine from a tube was filtered, and the filtrate used to determine enzymic action of the bacteria as in the former experiments for the yeast. At the same time 60 grams of pressed yeast were mixed with

[9] Hahn, M. Ber. d. deut. chem. Gesell., 1898, No. 2, pp. 200-201.
[10] Hahn, M., and Geret, L., l. c., pp. 202-205.

emery and ground in a mortar for an hour. Then a mash of the mixture was made with 20 cc. distilled water. The mash was put in a press and squeezed, the extract being filtered. The extract was used as in the former experiments, in addition to which 10 cc. were heated to 45° C. to precipitate the proteid matter.

The same quantity of pressed yeast was made into a mash with 20 cc. dis. water, saturated with thymol, but without any previous grinding. The extract from this was used in the same manner as that obtained from the ground yeast. This was allowed to stand for one hour, then pressed and filtered, the filtrate used as in the former experiment.

The purpose of this experiment was to determine if it be necessary to crush the yeast cells in order to obtain the enzyme. The following table shows the results obtained in the various experiments.

COMPRESSED YEAST EXTRACT, GROUND.

Experiment.	Age of Culture.	No. cc. Extract.	Time of Clearing.	Time of Liquefaction.	No. cc. Gelatine Liq.
Thymol gelatine	....	1.5	....	13 days.	2.0
Thymol gelatine + 1% NaCl	....	1.5	....	13 days.	3.0
Thymol gelatine + 1% Na_2CO_3	....	1.5	....	13 days.	3.0
Thymol gelatine	....	5.0	11 days.	17 days.	2.0
Thymol gelatine + 1% NaCl	....	5.0	Not clear.	17 days.	2.5
Thymol gelatine + 1% Na_2CO_3	....	5.0	Not clear.	17 days.	3.0
Egg albumen	....	1.5	....	13 days.	Shallow depression.
Egg albumen	....	5.0	Not clear.	17 days.	1.0
Yeast solution, heated to 45° C.	....	10.0	Not clear.	17 days.	No apparent action.

Average—T. g., 2.0; T. g. + NaCl, 2.75; T. g. + Na_2CO_3, 3.00.

COMPRESSED YEAST, WITHOUT GRINDING.

Thymol gelatine	....	5.0	Clear at start.	8 days.	2.0
Thymol gelatine + 1% NaCl	....	5.0	Clear at start.	8 days.	1.0
Thymol gelatine + 1% Na_2CO_3	....	5.0	Clear at start.	8 days.	3.5
Yeast solution	....	10.0	Clear at start.	8 days.	No apparent action.

BACTERIAL EXTRACT.

Experiment.	Age of Culture.	No. cc. Extract.	Time of Clearing.	Time of Liquefaction.	No. cc. Gelatine Liq.
Thymol gelatine	4 days.	1.5	Clear at start.	13 days.	2.25
Thymol gelatine + 1% NaCl	4 days.	1.5	Clear at start.	13 days.	2.00
Thymol gelatine + 1% Na_2CO_3	4 days.	1.5	Clear at start.	13 days.	2.75
Thymol gelatine	7 days.	3.0	Clear at start.	8 days.	4.00
Thymol gelatine + 1% NaCl	7 days.	3.0	Clear at start.	8 days.	1.75
Thymol gelatine + 1% Na_2CO_3	7 days.	3.0	Clear at start.	8 days.	3.00

Average—T. g., 3.12; T. g. + NaCl, 1.87; T. g. + Na_2CO_3, 2.87.

The results of the experiments show that the pure yeast excretes a proteolytic enzyme that is fairly active, and from the fact that it works in the presence of neutral and alkaline salts, it must be of a tryptic nature. It seems to be of the same nature as the trypsin extracted by Edkins, since it works best in the presence of NaCl.

The experiments on the compressed yeast and the bacteria obtained from the compressed yeast show undoubtedly the presence of an enzyme, but the indications point more strongly to a bacterial than to a yeast origin, since it was not necessary to break the yeast cells before the pressing in obtaining the enzyme, and also, since in experience with pure yeast cultures, only three cases have been noted in which any perceptible enzymic action took place. Then the bacterial extract was very strong, so that though only a comparatively small number of bacteria are present in the compressed yeast as compared with the yeast, the activity of the extract would be accounted for. Then again though the bacterial and compressed yeast extracts did not act uniformly, they showed the same peculiarity in the greater activity of the extract in the presence of Na_2CO_3. Work with a mixture of organisms is always open to the doubt in regard to the action of each organism.

DESCRIPTION OF THE YEAST.

The cells of this species are very variable in shape, being round, elliptic, elongated and irregular, slender at one end and widening out toward the other, or showing projections from the sides (Ill. 1). These irregularities occurring to the greatest extent in wort gelatine cultures (Ill. 2). In wort the cells become much elongated and are in long chains (Ill. 3), while in lactose solution the round cells predominate and occur mostly in pairs. Occasionally giant cells are found in the cultures. The cells which are round in a lactose solution, when placed in wort in a moist chamber, lengthen inside of twenty-four hours. (Ills. 4, 5.)

They vary in size, the round cells averaging 3.3 μ in diameter, while the average of the elongated are 3.3 μ by 10 μ.

This yeast does not ferment sucrose or lactose. It forms a fairly heavy sediment in the sucrose, but only a slight growth in the lactose. In dextrose it required six days for fermentation to start and twenty-four hours to form 3 cc. gas. In wort, which contains maltose, fermentation started in four days, and 25 cc. of gas were formed in three days, when the cul-

ture was kept at room temperature. but at 30° C., gas is given off in twenty-four hours.

In wort gelatine tubes the growth tapers from the surface along the needle track, having fine line of growth radiating from the main growth, then the gelatine gradually breaks down with the liquefaction.

The colonies at first are rather thick in the center with filaments radiating from the central mass. When liquefaction begins, which is inside of three days, the central mass breaks down and spreads as a sort of mycelial mass over the plate, resembling very strongly a mould growth when seen under the microscope; Ills. 6, 7, 8 show successive stages in the growth and liquefaction.

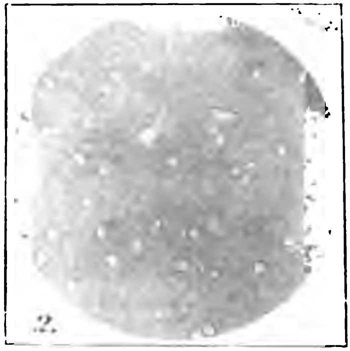
The species is undoubtedly S. liquefaciens, as described in Saccardo,[11] the cells showing the same variations and varying only slightly in size from that description.

EXPLANATION OF ILLUSTRATIONS.

1. Ten days' growth in wort. x320.
2. Two weeks' growth in wort gelatine. x450.
3. Sixteen days' growth in wort gelatine. x320.
4. Twenty-four hours' growth in wort in moist chamber. x334.
5. Round cells from lactose solution in moist charmber. x320.
6. Colony grown in wort gelatine, three days old. x30.
7. Colony grown in wort gelatine, four days old. x35.
8. Colony grown in wort gelatine, four days old. x35.

[11] Saccardo, P. A. Sylloge Fungorum, Vol. VIII, pp. 916-922.

1.



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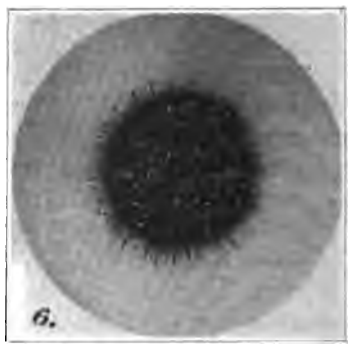


6.

7.

8.

SACCHAROMYCES ANOMALUS HANSEN(?)

BY KATHERINE E. GOLDEN.

In his investigations upon spore formation in yeasts Hansen found three typical groups, these three differing either in the form of the spores or in their mode of germination. The third type is furnished by S. anomalus, the spores of which are hemispherical in form, having a projecting rim around the flattened surface. The other two types are spherical in form, but differ in their mode of germination. Hansen found this species in an impure Bavarian brewery yeast, and after he had called attention to the peculiar spores, they were also observed by Holm, Lindner and Will,[1] who likewise found them in impure brewery yeast. These investigators did not determine whether the peculiar spores which they observed belonged to Hansen's S. anomalus or to allied species. Bay[2] gives the habitat as impure brewery yeast and grapes, as does Kayser.[3]

Hansen's[4] description of the yeast is very brief, as is also the description by Jörgensen[5] and that given in Saccardo[6] so that the form of the spores is the most characteristic feature.

A yeast which develops the same form of spores, I found associated with another yeast on the skin of lemon. This is a new habitat for the yeast, and I can find no mention of any such yeast occurring in this country.

The cells are round or oval, occurring either singly or in pairs, though occasionally in a vigorous growth in wort colonies consisting of many cells are found (photograph 1). The cells are very small, measuring 2.4 μ in breadth by 3.3 μ in length for the small oval ones to 6.6 μ in diameter for the cells containing spores (seen in photograph 2).

In wort gelatine plate cultures the colonies are of a dull, grayish white color, round, with rather even outline. They grow rather slowly under the best conditions. The photograph (3) shows a forty-eight-hours' growth. The wort gelatine plates seem to offer better conditions for the

[1] Jörgensen, A. Micro-Organisms and Fermentation, 1893, p. 182.
[2] Bay, J. C. Am. Naturalist, Vol. XXVII, 1893, pp. 685-696.
[3] Kayser, E. Les Levures, p. 104.
[4] Hansen, E. C. Central. f. Bakt., Bd. XIII, 1893, pp. 101-102.
[5] L. c., pp. 181-182.
[6] Saccardo, P. A. Sylloge Fungorum, Vol. VIII, pp. 216-228.

formation of spores than any of the other cultures, spores being found in four days at room temperature.

In both wort and beef broth gelatine tube cultures the growth is practically the same. The growth has a dry appearance and forms a dense mass at the needle puncture, without any tendency to spread. The growth tapers gradually from the surface along the needle track until at the bottom of the tube it is just perceptible. It has a characteristic crinkly appearance along its whole length.

Cultures in Pasteur solution, with 5 per cent. sucrose, lactose and dextrose, were made in fermentation tubes, and also in wort which contains maltose. In sucrose no fermentation occurred; there was a heavy growth, however, which caused a strong turbidity of the liquid in the bulb and a heavy sediment; the liquid in the tube remained clear. A film was formed which extended up the sides of the tube. After five days no spores were found either in the film nor in the sediment. Only a very slight growth occurred in the lactose solution, this forming a delicate film and a slight sediment. No gas was formed. The cells in lactose occur singly or in pairs and appear poorly nurtured (photograph 4). In the dextrose solution the growth was vigorous, forming a heavy sediment. Fermentation commenced in four days, and in twenty-four hours 5 cc. of gas were formed. In this, as in the sucrose solution, a strong film was formed. No spores were found in the film nor in the sediment even after seven days' growth. In the wort the fermentation was much more vigorous than in the dextrose, 10 cc. of gas being formed in the time that only 5 cc. were formed in the dextrose solution. Even before fermentation ceased a film formed in spots on the surface. In the wort a delicate ethereal odor is generated, which is very pleasant. Spores were just beginning to form in the film and sediment in eleven days.

Spores formed more readily in a wort gelatine plate culture than even in the regulation manner on a gypsum block. In the plate they formed invariably in four days, not to any great extent, but sufficient to be found in every microscopic examination. The cells in which the spores form are large, and just before the formation the protoplasm becomes very granular and refractive. As the culture ages and more spores are formed they are found free from the cell wall and in groups ranging from two to fourteen in number. Spores can be seen in photographs 5 and 6.

It is not quite certain whether this is the same species as Hansen's S.

anomalus, for the prominent characteristics in the description of that yeast are the peculiar form of the spores and their ready formation in both the film and sediment during fermentation. The shape of the spores in the yeast described is the same as that of Hansen's, but the earliest period at which spores were formed in fermenting wort was eleven days, and then very sparingly. In the other solutions used, no spores were formed even after three weeks' growth. Then no mention is made of their rapid formation in wort gelatine plates, and yet they form there very readily.

Taking into consideration the characteristics which are described by Hansen for S. anomalus—spore formation, size and shape of cells, and odor generated during fermentation—and comparing them with those of the yeast described, they agree fairly closely, but the characteristics which are not noticed seem to be sufficiently prominent to not have escaped attention if they existed in S. anomalus. Those are lack of fermentation of sucrose and the nonformation of spores in liquids other than wort. To me it seems that the two yeasts are similar, and the failure to note certain characteristics can be accounted for by the brevity of the original description.

EXPLANATION OF ILLUSTRATIONS.

1. Cells grown in beer wort. x700.

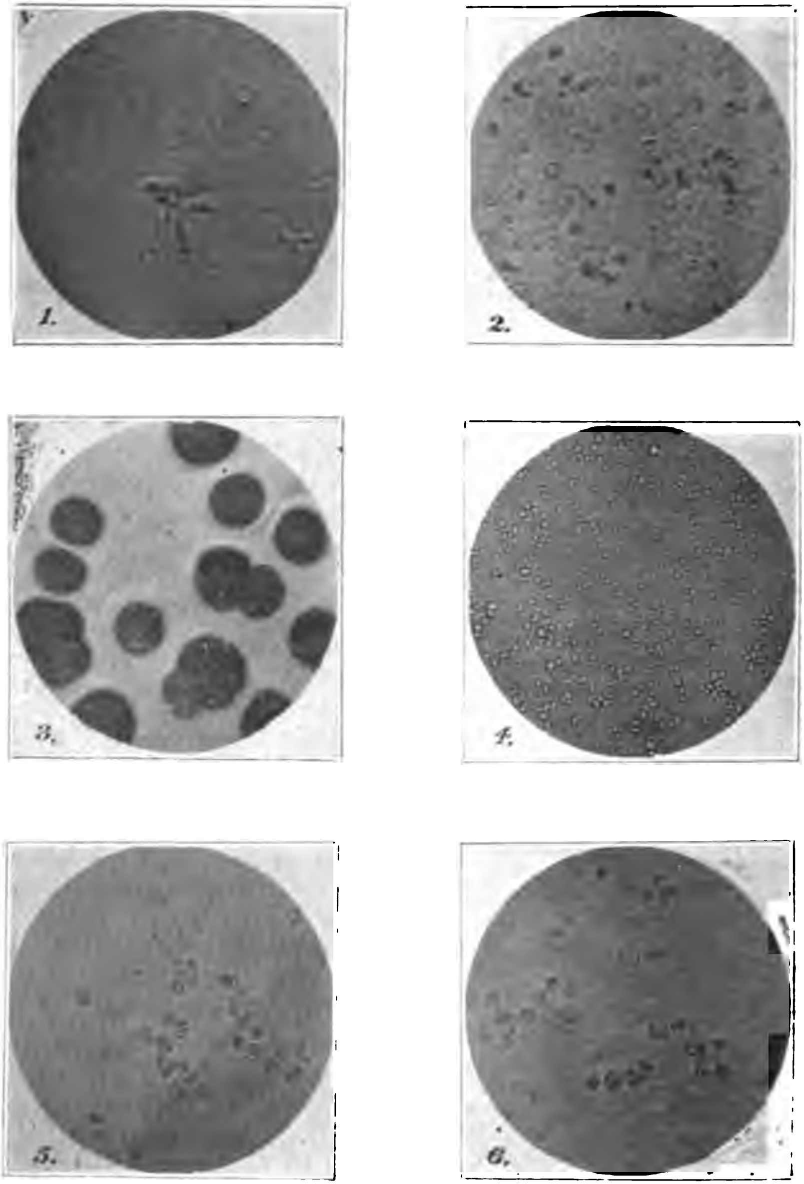
2. Eight days' growth in Pasteur solution containing 5 per cent. sucrose. x700.

3. Forty-eight hours' growth on wort gelatine plate. x30.

4. Ten days' growth in Pasteur solution containing 5 per cent. lactose. x320.

5. Cells showing spore development, from wort gelatine plate, ten days' growth. x700.

6. Cells showing spore development, from wort gelatine plate, two weeks old. x700.


1.
2.
3.
4.
5.
6.

Some Problems in Corallorhiza.

By M. B. Thomas.

Some recent discussions regarding the relation of endophytic mycelium to the roots of certain orchids and allied plants has suggested an investigation into this condition in the Orchidaceae, and the results show that out of fifty species of orchids examined all present this relation in a varying degree. The very peculiar root system of the plants of this family may be accounted for by the influence of this semi-parasitic condition.

In corallorhiza, no doubt most of the nutrient material taken in is through the agency of these very abundant hyphae, while in the cypripediums, though present, the hyphae do not play a very conspicuous part in the absorption of food by the plant.

The great abundance of the hyphae in certain green orchids leads us to infer that the presence of these threads alone is not sufficient to account for the very remarkable phenomena in certain colorless orchids like corallorhiza, etc.

In my judgment, other and less obvious changes will yet be determined that will assist in accounting for the very remarkable life history of corallorhiza.

The paper deals with some of the problems along this line and the results will be published elsewhere.

The Disappearance of Sedum ternatum.

By M. B. Thomas.

Attention is called to the very unusual condition of a plant in which modifications for adaptation to its peculiar environment failed to protect it from the severity of the fall and winter of 1898-9. Sedum ternatum Michx., a plant found in several localities previous to that time, completely disappeared, so that no trace of it remained in the local flora of Crawfordsville.

The paper, which is to be published in full elsewhere, deals with the history of adaptation in this plant.

A Preliminary Report on the Eye of the Mole (Scalops aquaticus machrinus).

By James Rollin Slonaker.

It is a general belief with many people that the mole does not have eyes. This is possibly due to the fact that the eyes are not readily seen and that an animal living habitually in the ground would have little or no use for organs of sight. But this, like many other common ideas, is wrong, for the mole has not only a well-defined eye, but one which is readily observed on parting the fur at the right place. It is seen as a dark area covered by the skin and true eyelids. The latter, however, are rudimentary and the cleft between them so small that it is practically never open enough to admit light. (Fig. 1.)

From this fact alone one could safely conclude that the power of sight in the mole is no more than to distinguish between light and darkness. But when the eye itself is examined this conclusion is well substantiated.

Comparing the mole eye with a normal mammalian eye it is found to be quite degenerate. The stages of degeneration seem to be in the following manner:

The eye decreases materially in size. This reduction diminishes the size of the aqueous and vitreous chambers until in some eyes they are wholly wanting. This allows the retina to collapse, causing the inner layers to become more or less jumbled together. Each of the layers may, however, be made out as is shown in Figs. 2 and 3.

The lens is much modified in size and shape in different eyes. Owing to the great diversity of pressure exerted by the shrinking eye the lens takes a variety of forms which may be decidedly different in eyes taken from the same animal. This is shown in Figs. 2 and 3, representing the right and left eye respectively, from the same animal. On magnifying the lens the cells are seen to resemble cartilage more than typical lens cells. (Figs. 4 and 5.) The histological degeneracy of the lens has thus gone much farther than one would at first suspect.

Ritter[1] and Rabl[2], in describing the development of the mole lens say

[1] C. Ritter, Die Linse des Maulwurfs. Arch. f. Micr. Anat. u. Entwl., Bd. 53, Heft III, p. 397.

[2] Carl Rabl, Ueber den Bau und die Entwicklung der Linse. Zeitschr. f. Wis. Zool., Bd. 67, Heft 1, 1899, p. 63.

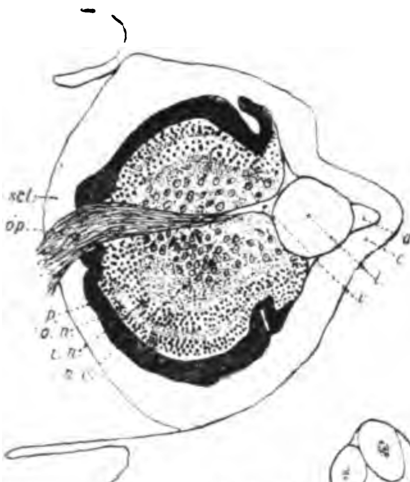


Fig. 3

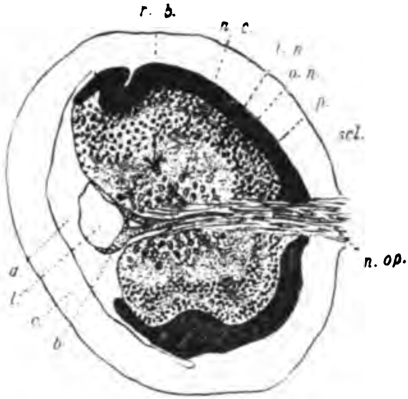


Fig. 2.

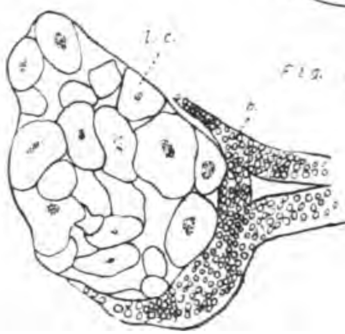


Fig. 5

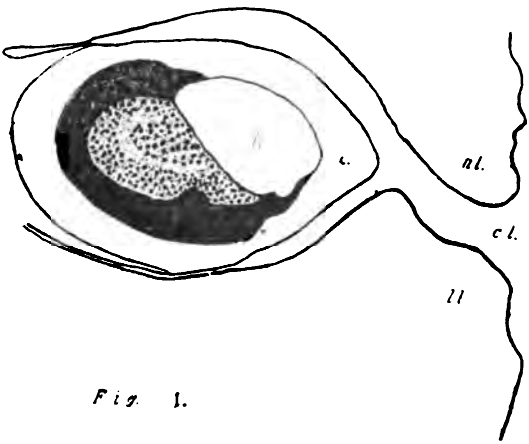


Fig. 1.

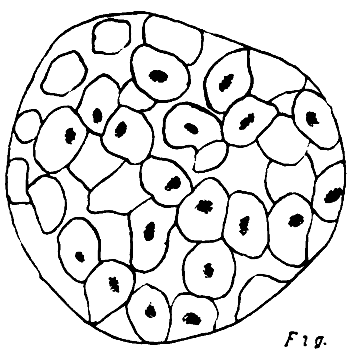


Fig. 4.

that it is similar to the mammalian type in its early stages, but the later stages are arrested, and in the adult the typical lens cells have degenerated to a form as above described.

The finer histological structures and relations of the different cells will be presented in a later paper.

The function of such an eye as this may be reasonably conceived when we consider the composition and shape of the lens, the almost closed lids and the closely crowded condition of the retina. The power of sight would doubtless extend little if any beyond the ability of distinguishing between light and darkness.

EXPLANATION OF FIGURES.

All the figures are semi-diagrammatic camera drawings of sections from the mole eye.

ABBREVIATIONS.

a. Aqueous chamber.

b. Blood vessel.

c. Cornea.

cl. Cleft between eyelids.

i. n. Inner nuclear layer.

o. n. Outer nuclear layer.

n. c. Nuclear or ganglion cell layer.

l. Lens.

ll. Lower eyelid.

ul. Upper eyelid.

r. b. Retinal blood vessel.

p. Pigment layer.

v. Vitreous chamber.

scl. Sclerotic coat.

n. op. Optic nerve.

l. c. Lens cells.

Fig. 1.—Vertical section through eye and lids showing the cleft between the lids. The section did not pass through the center of the eye. x48.

Fig. 2.—Vertical section passing through center of nerve and lens. The thickness of the different layers is correctly represented, but the cells are diagrammatic. x48.

Fig. 3.—Horizontal section through the left eye from the same animal as Fig. 2. The cornea is folded, due to the hardening fluid. x48.

Fig. 4.—Enlarged view of lens from the same eye as Fig. 3. The peculiar cartilage-like cells are shown. x270.

Fig. 5.—Enlarged view of lens from the same eye as Fig. 2. x270.

NOTES ON INDIANA BIRDS.

BY AMOS W. BUTLER.

The following notes are given here in order that they may be placed on record. In them are included such records of special interest as have been brought to my attention since the publication of my report on "The Birds of Indiana," at the beginning of 1897. In them, it will be observed, are added two species to the list of birds of this State. These are the Caspian Tern and Bachman's Warbler. There are also some interesting notes on the appearance of the Wild Pigeon.

AYTHYA VALLISNERIA (Wils.).

Canvas-back Duck.—A male and female were killed in the marsh at English Lake, Indiana, November 4, 1899. Never known to have been taken there in the fall before.

A single one was seen at the same place November 24, 1899. (Ruthven Deane.)

CLANGULA HYEMALIS (LINN.).

Old Squaw Duck.—February 12, 1899, a flock of thirteen Old Squaws alighted in the water where ice was being cut at English Lake, and all were killed. (Ruthven Deane.)

October 29, 1889, a specimen was taken at Calumet Heights, Indiana. This is a very early record.

LOXIA CURVIROSTRA MINOR (BREHM).

American Crossbill.—Dr. Stanley Coulter reports at least two dozen on Purdue University Campus November 3, 1898.

LOXIA LEUCOPTERA (Gmel.).

White-winged Crossbill.—Reported quite abundant around Chicago in the past two weeks. (Ruthven Deane, in Epist. 11-26-99.)

Reported from near Richmond, where a male was seen May 1, 1899, by Joseph F. Honecker.

A male was found dead beneath the electric wires at Greensburg, Indiana, November 7, 1899, by a little colored boy, who brought it to Prof. Geo. L. Roberts, in whose collection it now is. Upon investigation, a few minutes thereafter, Professor Roberts found six or eight others among the maple trees in a yard near by.

ECTOPISTES MIGRATORIUS (LINN.).

Passenger Pigeon.—Six were seen July 10, 1899, at St. Peters, Franklin County, Indiana; also found four nests near Oak Forest, Indiana.

October 23, 1898, a flock of sixty-eight was seen near Springfield in the same county. (Jos. F. Honecker.)

One mounted by Beasley & Parr, of Lebanon, was killed by Frank Young, Willson P. O., Shelby County, Indiana, near that place, about September 24, 1898. It was in company with two doves in a patch of wild hemp when found. The specimen is in the possession of W. I. Patterson, Shelbyville, Indiana.

Joseph F. Honecker has reported these birds several times from the vicinity of Oak Forest, Franklin County. Under date of July 13, 1898, he says:

"On June 13, 1898, I found a place where about forty wild pigeons were roosting in a woods about one-half mile from Oak Forest, Franklin County, Indiana. The owner of the woods informed me that the pigeons stayed there for the last three years, roosting on a maple tree which was blown down by a severe wind storm June 28 1898. The pigeons are, I think, staying in that same woods yet, but where I am unable to find out. The pigeons are breeding in the woods, as I found fourteen nests with nestlings. This is the third flock of wild pigeons I have seen in this county in the last five years."

STERNA TSCHEGRAVA (LEPECH).

Caspian Tern.—Mr. J. Grafton Parker, Jr., reports the identification of

five specimens of this Tern at Miller's, Indiana, in August, 1898. None were taken.

Mr. F. M. Woodruff, of Chicago, says the Caspian Tern is not a rare bird on the lake in the early fall. "A few are seen each year at Miller's, Indiana. They are very shy, but I have managed to obtain four of them."

HELMINTHOPHILA BACHMANI (AUD.).

Bachman's Warbler.—A female of this rare warbler was taken May 2, 1899, near Greensburg, Indiana, by Mr. W. F. West. The captor says: "It had no song. It was taken from the lower branches of a large elm tree, situated on the bank of a small stream which flows through an open woods." The following is the description: Forehead, sides of head, upper neck and breast, bright yellow; crown and band across neck, black; belly and under-tail coverts, whitish; above, back of head and neck, grayish; back, wing coverts and edge of quills, tinged with olive green; upper tail coverts, bright olive green; wings, grayish; tail apparently same color; but two feathers, however, remain for determination. Length, 4.50; tail, about 2.00; wing, 2.37. Male.—Greensburg, Indiana, May 2, 1899, Col. W. F. West.

It is interesting to note this extralimital record of this rare bird. Its range is South America and the Gulf States west to Louisiana; Cuba in winter. It has been taken as far north as southern Virginia and Arkansas.

Biological Conditions of Round and Shriner Lakes, Whitley County, Ind.

By E. B. Williamson.

Whitley County is situated in the northeastern part of Indiana. It is bounded on the east by Allen County, of which Fort Wayne is the county seat; Columbia City, situated very nearly in the center of the county, is the county seat of Whitley County. Round, Shriner and Cedar lakes lie in the northern part of the county, above seven miles from Columbia City. Shriner and Cedar lakes lie parallel to each other, directly west of Round Lake, into which they empty their waters. Round Lake is drained into

Thorn Creek, which leaves the lake on the south, passing into Blue River, then into Eel River, and so into the Wabash.

The outlet from Shriner Lake to Round Lake is a narrow artificial channel. The connection between Cedar Lake and Round Lake is formed by a marsh, grown up with cat-tail flag *(Typha latifolia)*, button-bush *(Cephalanthus occidentalis)*, swamp loosestrife *(Decodon verticillatus)*, and a variety of other marsh plants, with occasional stretches of open water.

But little time was spent about Cedar Lake. Its shores are covered with underbrush, and the bottom of the lake is so soft and, near the shore, so encumbered with tree trunks and branches that collecting is very difficult. A number of dragonflies were taken, but nothing was found here that was not observed at Round and Shriner.

Shriner Lake is one and one-quarter miles long, east and west, and one-quarter of a mile wide.* A small stream, which is dry most of the year, enters the lake at its southwestern part; but springs are almost the entire source of water supply. The temperature for some points at the bottom of the lake is as low as 50 degrees. The shores are sandy, and, with the exception of a portion of the northern part, solid and firm. Generally the bottom slopes rapidly from the shore line of deep water. The greatest depth is over seventy feet. Back from the water line the shores rise in low bluffs, covered with oak, maple and beech timber. A few sycamores and cottonwoods grow near the water's edge. About the western and northwestern parts of the lake the land has been cleared, and is now under cultivation.

The flora of the region is rich. Among the more conspicuous plants the following may be mentioned: Water-lily *(Nymphæa odorata)*, spatter-dock *(Nuphar advena)*, water-shield *(Brassenia peltata)*, bladderwort *(Utricularia vulgaris)*, stiff white water-crowfoot *(Bidens Beckii)*, water-weed *(Elodea Canadensis)*, cat-tail flag *(Typha latifolia)*, arrow-head *(Sagittaria)*, pickerel-weed *(Pontederia)*, several species of pondweeds *(Potamogeton)*, pipewort *(Eriocaulon septangulare)*, dulichium *(Dulichium arundinaceum)*, several species of spike-rush *(Eleocharis)*, several species of bullrushes (among them *S. atrovirens*, *S. lineatus*, *S. Americanus*, and *S. lacustris)*, beak rush *(Rhynchospora glomerata)*, bog rush *(Juncus Canadensis* var. *longicaudatus)*, and several species of *Cyperus*. Thistles, goldenrods, asters, mints, knotweeds *(Polygonum)*, and blue flag *(Iris)*, with a variety

*For this and a number of other facts I am indebted to the Biennial Report of Mr. P. H. Kirsch, State Fish Commissioner of Indiana, for the years 1895 and '96.

of grasses and smaller sedges cover the shores. In adjoining woodlands I have found two species of orchids, the nodding pogonia (P. trianthophora) and the coral-root *(Corallorhiza odontorhiza).*

Round Lake is seven-eighths of a mile long and one-half of a mile wide. The water supply is derived from Cedar and Shriner lakes. Round Lake is shallower and warmer than Shriner and the water is less clear. Excepting small stretches of sandy beach along the northeastern and southern sides, the shores of the lake are soft and miry. The dredging of Thorn Creek has lowered the lake until at several places at a distance from shore the potamogetons reach the surface of the water. Lowering the lake five feet more will fill it with sand bars or even reduce it to a number of ponds. An extensive tract near the head of Thorn Creek, which five years ago was a swamp, is now under cultivation. Among the farmers of the neighborhood the practice is common of planting artichoke among the spatter-dock where the lowering of the lake has exposed the land. In the fall this is turned over to hogs and their persistent rooting in the soft earth pulverizes and dries the soil most effectually.

The vegetation about Round is ranker even than about Shriner Lake, and spatter-dock *(Nuphar)*, which is rather rare there, almost surrounds this lake. In September, 1897, my friend, Mr. C. C. Deam, of Bluffton, Indiana, found the reversed bladderwort *(Utricularia resupinata)* growing along the western shore. Greater bladderwort *(U. vulgaris)* is abundant, and with potamogetons, eel grass *(Vallisneria)*, hornwort *(Ceratophyllum)* water-milfoil *(Myriophyllum)*, and stiff white water-crowfoot completely clothes the bottom of the shallower parts of the lake.

Not only is the vegetation more luxuriant about Round Lake than about Shriner, but the former lake seems biologically richer in every way. Shriner is a beautiful, deep, clear, blue reservoir of spring water, while Round Lake is a warm, shallow basin, surrounded by marshes, and containing the overflow of two lakes, and the drainage of neighboring woods and fields. Mr. Kirsch has recorded twenty-one species of fish for Shriner Lake and twenty-five species for Round Lake. I have not observed any crawfish at Shriner Lake, but about the shores of Round Lake the burrows and chimneys of *Cambarus diogenes* are common. While the two lakes have each furnished about the same number of species of dragonflies, these insects are usually much more numerous about Round than about Shriner.

Of the vertebrates of this region the following species may be noted: Mammals—moles, shrews and mice are common. Gray squirrel *(Sciurus carolinensis)* are rare, fox squirrels *(S. niger* var. *cinereus)* common and red squirrels *(S. hudsonicus)* and chipmunks *(Tamias striatus)* abundant. Minks *(Lutreola vison)*, weasels *(Putorius noveboracensis)* and 'coons *(Procyon lotor)* are common; and woodchucks *(Arctomys monax)* burrow in the hillsides in considerable numbers. Birds: Green herons *(Ardea virescens)* visit the lakes frequently, great blue herons *(Ardea herodias)* rarely; Virginia rails *(Rallus virginianus)* and least bitterns *(Botaurus exilis)* have been occasionally observed. Red-winged blackbirds *(Agelaius phoeniceus)* are very abundant. Summer yellow-birds *(Dendroica aestiva)* nest in numbers in the button-bushes in the marshes. In 1895 long-billed marsh wrens *(Cistothorus palustris)* nested in the vicinity of Round Lake, but during 1898 none were seen or heard. During 1896 a loon *(Urinator imber)* spent the summer at Shriner Lake, where it might have been seen almost any day. Sandpipers *(Actitis macularia)* and killdeers *(Aegialitis vocifera)* are common. An occasional Bartramis sandpiper *(Bartramia longicauda)* is seen in flocks of the latter species. Reptiles: Of the turtles the western painted turtle *(Chrysemys marginata)*, mud turtle *(Aromochelys odorata)* and snapping turtle *(Chelydra serpentina)* were the only species observed. These three are common or abundant. Three species of snakes are often observed about the lakes: Water snake *(Tropidonotus sipedon)*, garter snake *(Eutania sirtalis)* and riband snake *(Eutania saurita)*. The blue lizard *(Eumeces fasciatus)* is not rare in adjoining woodland. Amphibians: Spotted frogs *(Rana virescens)* are very abundant, and bullfrogs *(Rana catesbiana)* rather rare. Fish: An abundance of game and food fish are found in these lakes. Of the two Round Lake is regarded as affording the best fishing grounds. Yellow perch *(Perca flavescens)*, large-mouthed black bass *(Micropterus salmoides)* and a number of species of sunfish *(Lepomis)* are those most usually taken. Catfish, both the yellow cat *(Ameiurus natalis)* and bullhead *(Ameiurus nebulosus)*, and pike *(Lucius lucius)* are more rarely met with. Occasionally the calico bass *(Pomoxis sparoides)* and the warmouth *(Chaenobrythus gulosus)* are taken in considerable numbers about the east end of Shriner Lake. The latter species is called mud bass, and the calico bass is referred to as rock bass by the local fishermen. This confusion of common names is odd for the reason that while the warmouth *(Chaenobrythus gulosus)* much resembles the rock bass

(Ambloplites rupestris) the calico bass *(Pomoxis sparoides)*, to which the name "rock bass" has been applied, has but little general resemblance to this fish.

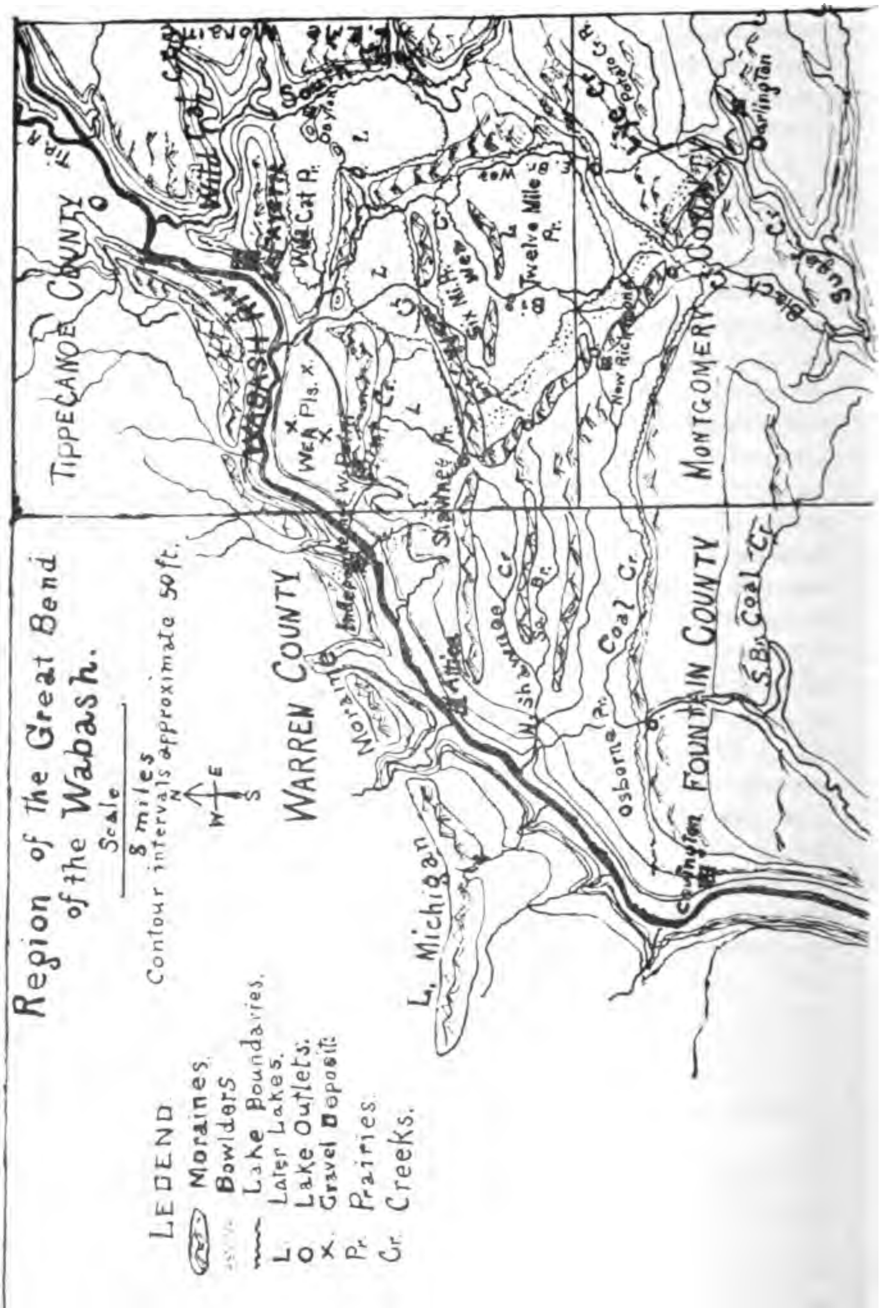
Molluscans are rare about either lake, but are more common about the eastern shores of Round Lake than elsewhere.

Of the insects, Neuroptera, Orthoptera and Diptera are most numerous. Lepidoptera, Coleoptera and Hymenoptera are less conspicuous. The Odonata fauna is the richest and most characteristic. On June 8, 1898, the air was alive with larger species, and in the shore-line grasses and sedges smaller forms swarmed in countless numbers. From May until December they are fully entitled to rank as the most attractive and interesting insects of this region. Strong and fierce, constantly warring among themselves, so far as observed in the perfect-winged state they suffer defeat from only one quarter. In the webs of a species of large black and yellow spider *(Argiope)* I have found the remains of *Argia violacea, Libellula pulchella* and *Mesothemis simplicicollis*. Of the two latter species only very teneral individuals were found so entrapped. Sunfish often dash at Libellulas when they are ovipositing, but I have never seen the dragonflies injured by these attacks.

The only two common names I have heard used in northern Indiana for the insects are "snake-feeders" and "snakedoctors." The belief that they can sting is almost universal. To the good people living about the lakes in Whitley County the occupation of the collector is beyond understanding. From his first appearance till his final departure he is plied with questions, his answers only confirming his questioners in their notions as to his mental instability. Among other questions I may record the following: "Are you getting snake-feeders for bait?" "To eat?" "To use their wings to make picture frames or ornaments?" "Or is there a bounty on them?"

The Eyes of Cambrus Pellucidus from Mammoth Cave.

By F. M. Price.


Region of the Great Bend of the Wabash.
Scale
8 miles
Contour intervals approximate 50 ft.
LEGEND
Moraines.
Bowlders
Lake Boundaries.
L Later Lakes.
O Lake Outlets.
X Gravel Deposit.
Pr. Prairies.
Cr. Creeks.
TIPPECANOE COUNTY
WARREN COUNTY
FOUNTAIN COUNTY
MONTGOMERY
L. Michigan
Moraine
Attica
Covington
Osborne Pr.
Coal Cr.
S.B. Coal Cr.
Shawnee Cr.
Shawnee Pr.
Wea Pls.
Wild Cat Pr.
Twelve Mile Pr.
Six Mi. Pr.
New Richmond
Darlington
Sugar Cr.
Black Cr.
Lafayette
Dayton

Cortex Cells of the Mouse's Brain.

By D. M. Dennis.

The Physical Geography of the Region of the Great Bend of the Wabash.

By William A. McBeth.

The region here considered embraces most of the area of Tippecanoe, the north half of Fountain and Montgomery and the southeastern border of Warren counties, lying in that part of Indiana where the Wabash River, after traversing the State nearly its entire width, turns abruptly to the south, which direction it follows through the remainder of its course.

The area embraces some of the most beautiful and fertile country in the State. Much the greater part is prairie, not continuous but divided by gentle ridges, usually timbered, into smaller sections locally named as Osborne's Prairie in western Fountain County, Shawnee, Twelve Mile, Six Mile and Potato Creek prairies further east, and north of these Wea Plains and Wild Cat prairies.

The main water-shed has a northward slope from northern Montgomery County to the Wabash, the main drainage line of the region. The slope rises rapidly to the east from the eastern side of the South Fork of Wild Cat Creek, and the country becomes distinctly a timbered region with clay soil. The southern divide is also a clay and naturally heavily timbered region, with a few narrow re-entrant strips of prairie. The country is diversified by several ridges and a great number of small gravel hills or mounds. The country to the north of the Wabash to a distance of from two to six miles from the river is a clay country, much of it still heavily timbered and very much broken by the knobs and basins characteristic of moraine topography. The country bordering the region on the south has this characteristic topography but of a more subdued type. Subordinate to these are several ridges, the relation of which to the others is not in every case clearly apparent. One of these extends almost due east from the town of West Point, Tippecanoe County, a distance of twelve miles, where it bends southeast and extends to the southeast

corner of Tippecanoe County. From this angle there also extends a broken chain of mounds northeast to near Dayton. Another well defined ridge, from the low crest of which rise many mounds, extends southeast from near Independence, on the Wabash, to Darlington, Montgomery County. Parallel with it on its eastern slope lies the belt of bowlders well known to Indiana geologists. Shorter and less conspicuous ridges extend east and west, at distances of about three miles apart, across the part of Tippecanoe County further south. Two or three such ridges traverse the northern part of Fountain County. Many mounds dot the region in no discernible relation to each other or to the chains and ridges. All these ridges and mounds of gravel have the regular stratification of water-laid deposits.

The drainage of the region is interesting and peculiar. The Wabash crosses Tippecanoe County through an immense deposit of gravel extending from the eastern to the western boundary of the county, having a width of from one to six miles and from two to three hundred feet deep. Between Warren and Fountain counties, from the western side of Tippecanoe to Portland, Fountain County, the stream runs on bedrock in a valley about a mile wide and one to two hundred feet deep. The smaller streams of Tippecanoe County, south of the Wabash, converge from the eastern and southern more elevated clay plains and the line on the southwest formed by the Darlington-Independence ridge. West of this the streams run west into the Wabash. The unusual course of the Wea Creek and of Coal Creek should be noticed particularly, the course of the former, forming a great semicircle, the latter having a course with an abrupt bend in it strangely similar to that of the Wabash. It should be noted also that the streams just over the south and southwest divides of the Wea basin in several places have their sources very near those of this basin, and in all such places there is a sag or connecting valley across the divide. Notice, for examples, the heads of South Flint and North Shawnee, Little Wea and Big Shawnee, Big Wea and Coal creeks. Note also the nearness of the northward-flowing tributary of Shawnee to the elbow in Coal Creek.

The foregoing statement of topographic facts is made in view of a possible solution of some problems that are suggested by them.

Mr. Chamberlain has called this a region of readjustment in glacial movement, and this statement seems to be the key to the solution of the problems that present themselves. When the last great North Ameri-

View of Part of Shawnee Prairie, Tippecanoe County, Indiana. (Bed of an Ancient Lake).

Shawnee Mound, South Slope, Tippecanoe County, Indiana.

Cook's Mound, Two Miles Southeast of New Richmond, Montgomery County, Indiana.

can ice sheet invaded Indiana it sent forward advance columns along the lines of low depression. Of these lines, the principal ones, a southward-moving lobe from the Lake Michigan depression, a southwestward-moving lobe from the Saginaw-Huron depression, and a west southwestward-moving lobe from the Erie depression, converged in northern Indiana, became confluent and moved southward to central Indiana. The climate then became warmer and the ice sheet began its retreat in an order the inverse of its advance. It melted away on the divides first and persisted much later in the lines of depression. Immense quantities of water from the melting ice, the accumulated precipitation of countless ages set free from its long bondage by the Frost King gathered in lakes in the depressions of the vacated regions, or swelled to immense size the streams that ran from the ice front. A new topography was imposed upon the region of glacial action. It is as a detail in the general scheme that the region described finds its explanation.

The converged lobes before mentioned moved down to the Shelbyville moraine extending from northern Vigo County northeast through Parke, east through Putnam and thence southeast. This moraine extends as a continuous plain, trenched by streams, bearing on its surface the weak dome-shaped swells that mark it as morainic in character to the northern part of Montgomery County, extending northwestward to and across the Wabash, which was one of its great terminal drainage lines, into which flowed Raccoon and Sugar creeks, mighty streams from the ice border further east. As the ice retreated to the present divide between Sugar and Coal creeks, the slope descending to the north was gradually uncovered, and a lake began to form along the southern border of the glacier, which overflowed south across the divide by Potato, Lye and Black creeks to Sugar Creek. Later, Coal Creek took its way west along the ice border and finding an outlet stream running south, or a southward bend in the ice front, it turned south at the elbow. This being lower than the outlets further east caused their abandonment, the water flowing through the sags in the Independence-Darlington Kame Moraine. This moraine is a weak frontal moraine of the Erie lobe and it was laid down in the lake and perhaps afterwards much dissected by wave action. The ice sheet halted for a long time at the West Point, or what is better known as the High Gap Ridge, the drainage then being by Flint Creek along its front across the divide to Shawnee, thence west into the Wabash, the terminal drainage stream of the Michigan lobe, the Wea-Coal Creek outlet being

probably still maintained. The High Gap Ridge is thought to be a moraine of the Michigan lobe. Later the ice retreated to the great moraine north of the Wabash, which river then extended itself from the great bend northeast along the border of the Michigan lobe in its present course. The lake held in the Wea basin then formed an outlet stream to the north and Wea Creek and its tributaries came into existence, the main stream following the moraine on the east and north sides where the deepest part if the lake nad been. The retreat continuing, the region east of Lafayette as far as Dayton, held a lake which flowed out where the moraine running east from West Point bends to the southeast at a low sag locally known as Dismal Swamp. Later an outlet opened into the Wea at the west end of the lake, the bed of which is now known as Wild Cat Prairie. Later still an outlet was formed at the east end of this lake by the South Fork of Wild Cat Creek extending headward from its junction with Middle Fork along the western border of the Erie lobe.

The Michigan and Erie lobes were now becoming differentiated again. The heavy moraine north of the Wabash is a terminal moraine of the Michigan lobe, the rapidly rising till plain east of the junction of Wild Cat Creek is the main frontal moraine of the Erie lobe. Tippecanoe River in its lower course is a former outlet of an interlobate lake which existed for a long time before being finally drained westward by the retreat of the Michigan lobe. The great gravel deposit is probably the filling of a lake produced by the melting of a thick bed of ice which had filled a preglacial valley. The present Wabash Valley is the trench cut out by the sand-laden stream which for thousands of years carried the water from the still retreating Erie lobe.

Different layers of bowlder clay with beds of gravel interposed point to minor advances and retreats of the edge of the ice sheet over all the region.

The facts here set forth are derived from an intimate knowledge of much of the region and considerable field work in the portions not so familiar and the conclusions are set forth as a working hypothesis subject to revision upon the basis of further examinations. The hypothesis postulates the presence of the Michigan and Erie lobes in the region at the same time, which is a view not agreed upon by all who have studied the glacial phenomena of North America.

An Interesting Bowlder.

By Wm. A. McBeth.

On the lawn in front of the residence of Thomas B. Miller, one-half mile north of New Richmond, Montgomery County, Indiana, stands the very interesting bowlder, a cut of which is given herewith. It is nearly five feet in length, and from two to three feet in diameter. It is roughly cylindrical in shape, and so white as to give most people who see it the impression that it has recently received a copious coating of whitewash. A closer examination shows a curious and beautiful structure, which may be compared to that of an immense stick of white taffy, strands of which had been drawn out into small ropes, braided, twisted and then doubled or folded, given a final pull and allowed to cool.

A small fragment analyzed at the chemical laboratory of Rose Polytechnic Institute, Terre Haute, Indiana, by Mr. J. W. Shepherd, was pronounced foliated serpentine. It was found in excavating the cellar of the residence, in front of which it stands. A smaller bowlder of the same material, and no doubt a fragment of the larger one, was found near it in the excavation.

The location in on the ridge of the Darlington-Independence Kame Moraine and near the parallel bowlder train mentioned in the article on the Physical Geography of the Great Bend of the Wabash. Its presence, in the region where found, may be explained in the same way that the presence of the thousands of others may be explained, but its composition and structure mark it as so uncommon that its source would throw much light upon the direction and distance of movement of the drift in the region where it was found. It is hoped that this description may meet the eye of some person who can give information as to its probable source.

Bowlder of Foliated Serpentine, New Richmond, Indiana.

Headwaters of Salt Creek in Porter County.

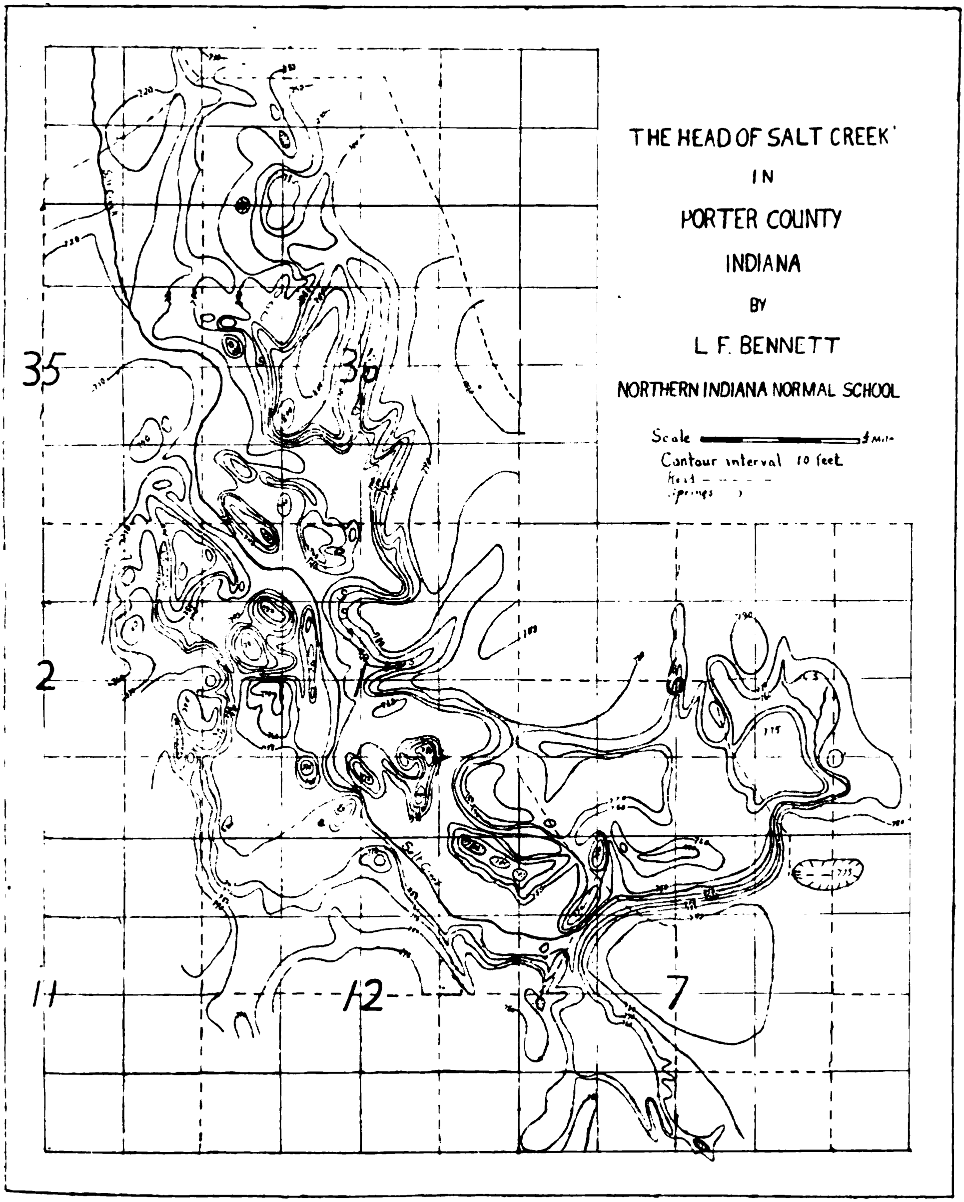
By L. F. Bennett.

Salt Creek rises three miles southeast of the city of Valparaiso, in section 6, 35 north, 5 west. It flows southwest one mile, thence in a north-northwesterly direction, cutting through the crest of the Valparaiso Moraine, and empties into the Calumet River in section 31, 37 north, 6 west. This paper has to do with the first four miles of its course.

Like many creeks in a drift region, it pursues a winding course through a marsh varying in width from one hundred yards to nearly a mile; and unlike most creeks it has several islands situated in its marshy bottom near its headwaters. These islands have their longer axes parallel with the general direction of the creek in that locality. They are from ten to fifty feet higher than the surrounding marsh and are from fifty yards to one-fourth of a mile in length. There are also tongues of land extending, in a few instances, one-fourth mile from the higher land and are connected with the higher land by low necks. The banks of the marsh, as a rule, are quite steep, and rise from forty to eighty feet above the creek bed. The marsh has so little slope that with the present price of land, it is not worth draining. It is so wet and uneven in most places that it is worthless for pasture. In the southwest quarter of section seven, there is a tributary marsh about ten feet above the level of the main marsh, and about forty acres in extent. It is connected to the larger marsh by a narrow channel. The sides of the marsh are from ten to twenty feet high and rather abrupt. During the greater part of the year there is no water in the connecting channel.

The flat marshy creek bottom, with its islands, tongues of land and abruptly sloping banks, furnishes a marked exception to the nearly level topography of the region to the south and east, which slopes very gradually to the Kankakee River.

The islands, and without doubt, many at one time were really such, are the most interesting features. Some are as high as the adjacent land on the sides of the marsh from which they appear to be cut; many have been eroded until they are but little above the general level of the marsh, and others have been nearly cut into two parts by unequal erosion They show every variety as to shape and height above the general level.


THE HEAD OF SALT CREEK
IN
PORTER COUNTY
INDIANA
BY
L. F. BENNETT
NORTHERN INDIANA NORMAL SCHOOL
Scale
Contour interval 10 feet
35
36
2
11
12
7
Salt Creek

The origin of the creek and its various features is a very interesting problem. It probably began as an original depression in the moraine, and, as at present, was fed by springs, the action of which is very apparent all along the creek's upper course. The head of the creek is formed by a number of small springs issuing from a low bank, and at various places many large perennial springs are found.

In section 2 (see map), on the east side of the creek, the springs have eaten back the bank until a terrace has been formed. This terrace is ten feet above the marsh, is from ten to seventy-five yards in width, is one-fourth of a mile long and in all places is composed of soft wet ground, showing that water is still issuing from beneath. From the terrace the land abruptly rises ten to twenty feet to nearly level ground.

If the tongues of land with their low necks are to be considered as islands nearly cut off and are to explain the origin of the islands, then there must have been a time when the quantity of water was much greater than at present. If there was more water most of it must have come from springs, as there is no evidence of water action except in the creek bed, the land on all sides being high and nearly level. Again, if the springs were more numerous and carried more water than at present, other evidence of their presence than that given above has entirely disappeared.

The narrow necks appear to have been cut out by the recessions of springs on opposite sides toward each other and which have dried up with changing climatic conditions.

There is no way at present to tell how deep the creek bed has been, as there are no wells of which sections may be obtained, except on the sides of the marsh and they are very shallow.

The accompanying contour map will give a good idea of the position of the islands and tongues of land with their relative heights. The contour interval is ten feet. The elevations were taken with an aneroid barometer and locations were made with a considerable degree of accuracy.

The Weathering and Erosion of North and South Slopes.

By Glenn Culbertson.

The experience of the writer in climbing the hills of southeastern Indiana, and especially those in the vicinity of Hanover and Madison, led to the opinion that, in certain valleys, there was a considerable variation in the inclination of the slopes.

During the last few months accurate measurements of the inclination of the slopes, of the depth and of the direction of trend, of four valleys or ravines were made with a view to ascertaining the amount of variation in the inclination of the slopes, and a reason for the variation where it was found.

The valleys or ravines, chosen for the measurements, are locally known as Butler, which is about one-half mile south of Hanover; Crowe, which borders the Hanover College campus on the south; Happy Valley, which borders the college campus on the north, and Clifty, which is located about two miles west of Madison.

The hills in the region of these valleys are capped with the so-called bluff limestone of the Niagara formation, the Clinton, and the Madison beds of the Ordovician. These rocks are comparatively uniform in texture and hardness throughout the region concerned. Butler, Crowe and Happy Valley ravines are less than a mile in length, and Clifty is but little more than two miles in length, from the mouth to the falls, which are found in each valley. The depth of these valleys, however, is approximatey 260 feet, aneroid measurement. The valleys are eroded to the level of the Ohio River, into which the streams occupying them empty.

The great depth of the ravines, as compared to their length, is accounted for by the fact that the Ohio-Wabash divide in this region approaches in places to within a mile and a half of the Ohio River.

The streams which have formed the valleys, across the lower portions of which the sections were made, are all small, and, with the exception of Clifty, are just able to transport the materials brought into them and do not erode the sides to any extent. Hence, we have in these valleys exceptional conditions for the study of the weathering and erosion of slopes.

Two sections were made across each valley with the exception of

Butler, and in each case the sections were intended to be fair averages of the slopes. The following data were obtained as an average result of the sections made in each valley.

BUTLER RAVINE.

Direction of trend, north, 70 degrees west.
Inclination of south slope (i. e., slope facing south), 25 degrees.
Inclination of north slope, 28 degrees.
Depth, approximately, 260 feet.

CROWE RAVINE.

Direction of trend, north, 80 degrees west.
Inclination of south slope, 22 degrees.
Inclination of north slope, 26½ degrees.
Depth, 260 feet.

HAPPY VALLEY RAVINE.

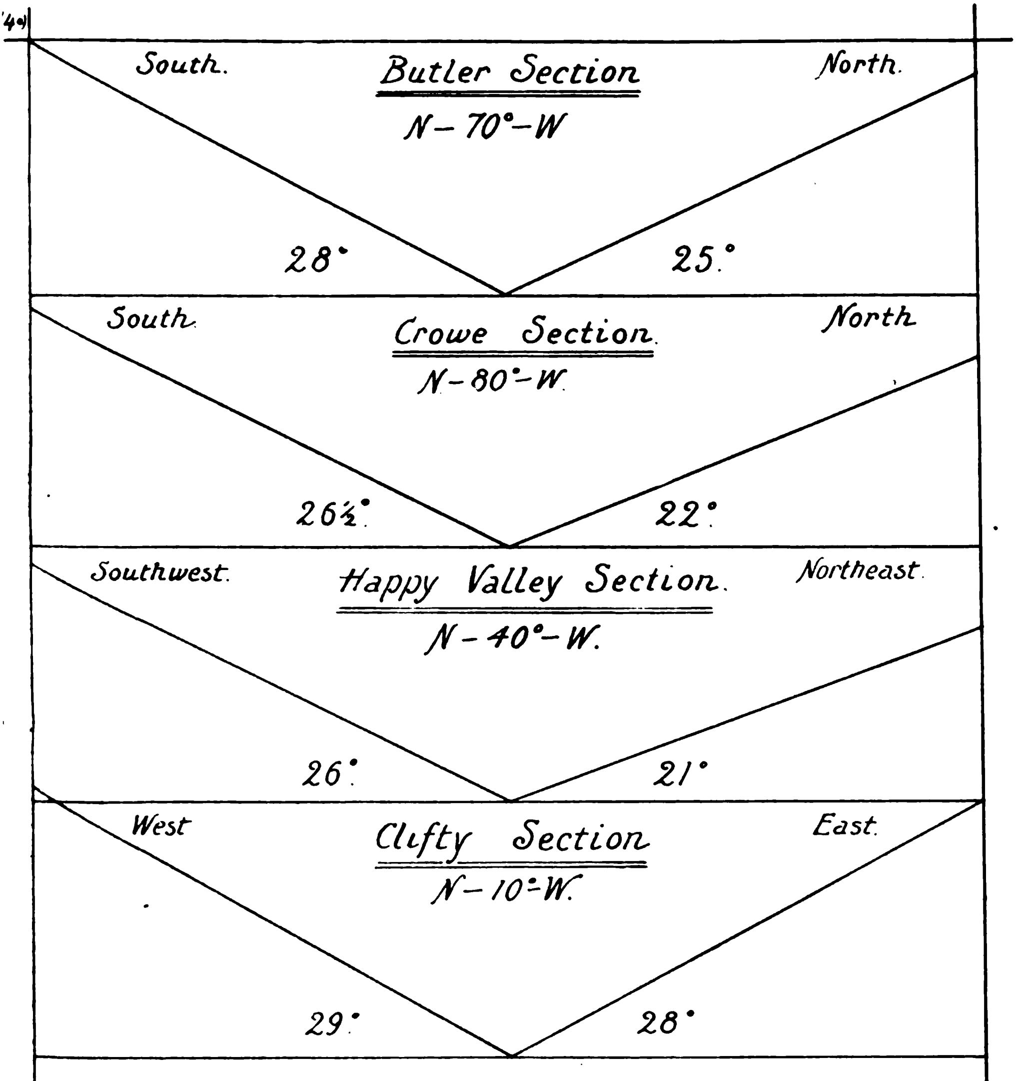
Direction of trend, north, 40 degrees west.
Inclination of southwest slope, 21 degrees.
Inclination of northeast slope, 26 degrees.
Depth, approximately, 255 feet.

CLIFTY VALLEY.

Direction of trend, north, 10 degrees west.
Inclination of west slope, 28 degrees.
Inclination of east slope, 29 degrees.
Depth, approximately, 270 feet.

(Reference to the accompanying figures will aid much in appreciating the variations in the slopes.)

These cross sections indicate a decided variation in the rate of weathering on the two slopes, in the cases under consideration, where the direction of valley trend is from east and west to southeast and northwest approximately, but that there is little variation where the valley trends approximately north and south. Sections taken of other valleys extending in a general north and south direction verify the latter statement.



Cross sections of four valleys near Hanover, Ind., showing the inclination of the slopes.

The direction of the trend of each valley is placed below the name.

The cause of the more rapid weathering of south slopes (i. e., those facing the south) is, no doubt, partially due to expansion and contraction. The massive rocks of the Niagara, Clinton and Madison beds of the Ordovician have been more rapidly broken to pieces on the south slopes than on the north, because of the much greater daily change of temperature on the south than on the north slopes. This is especially true during the winter season.

The chief agent, however, in producing the variations in the sections noted, is that of frost. The action of frost in producing such variation is three fold. First, the almost daily thawing and freezing of the moisture in the rocks of the south slopes during the winter produces a more rapid disintegration of these rocks, than would take place on the north slopes, where thawing occurs but few times comparatively during the winter season.

Again the surface soil of the slopes facing the south goes through the freezing and thawing process several scores of times during the winter, while that of the north slopes remains frozen almost continuously during the average wintry season. The "creeping of soils," resulting from frost action, is too well known to need explanation here, and must, to a large degree, account for the variations noted.

Again, the soil of the north slopes is frequently frozen, and even covered with snow or ice, while that of the south slopes is unfrozen. Hence, the erosive action of many winter rains is almost nothing on the north slopes, while it may be quite marked on the south slopes. This is an additional cause for the variation noted in the sections taken.

With the exception of the north slope of Crowe Ravine and the east slope of Clifty, the region considered is all wooded, while the unwooded slopes have been so but for a few years. What the effect of weathering and erosive agencies may be upon north and south slopes of land from which the forest trees have long been removed, has not been investigated, but from the greater abundance of loose stones on the south slopes of cleared and more or less neglected land, it is probable that the variation in the effects of weathering and erosion on the north and south slopes is even more striking than in the case of land covered with forest growth.

A Cranium of Castoroides Found at Greenfield, Ind.

By Joseph Moore.

Castoroides has been correctly represented as decidedly the greatest rodent, recent or fossil. This Greenfield cranium, with the nasals and premaxillary restored, would measure a foot and an inch in length. Compare this with the heads of beavers and ground hogs, the largest rodents with which we are familiar. Even the great capybara of South America is quite dwarfed in the comparison.

The scarcity of Castoroides remains and the interest which for various reasons attaches to them make every considerable fragment of them worthy of mention. So far as relates to material for study, Indiana has furnished far more than any other State. On this point, and for further details, I refer the reader to a detailed report of the Randolph County skeleton in the Journal of the Cincinnati Society of Natural History for October, 1890, and also to the American Geologist, Vol. XII, August, 1893. In the latter, mere mention is made of the cranium now under consideration. At that time it was the property of Dr. M. M. Adams, of Greenfield.

To said Dr. Adams I am greatly indebted for the transfer of the same to the Earlham College museum.

Little is known of its history save that it was found, years since, by some one who was digging or grading in Greenfield or vicinity.

It is the cranium of a larger representative of the species than the Randolph find, as described in the American Geologist and in the Cincinnati Journal. Although the thin pterygoid blades are badly broken away, still that characteristic feature of the double posterior nares is clearly shown.. This is especially noteworthy as it pertains to no other known species, fossil or recent.

This giant beaver-like rodent occupied our marshes and streams of quaternary times in company with the mastodon and mammoth, and probably became extinct, largely through the agency of prehistoric man, somewhat as our modern beaver appears to be going to-day.

The two plates, with explanations, which accompany this paper, will give a better idea of the dimensions and also of a few anatomical details.

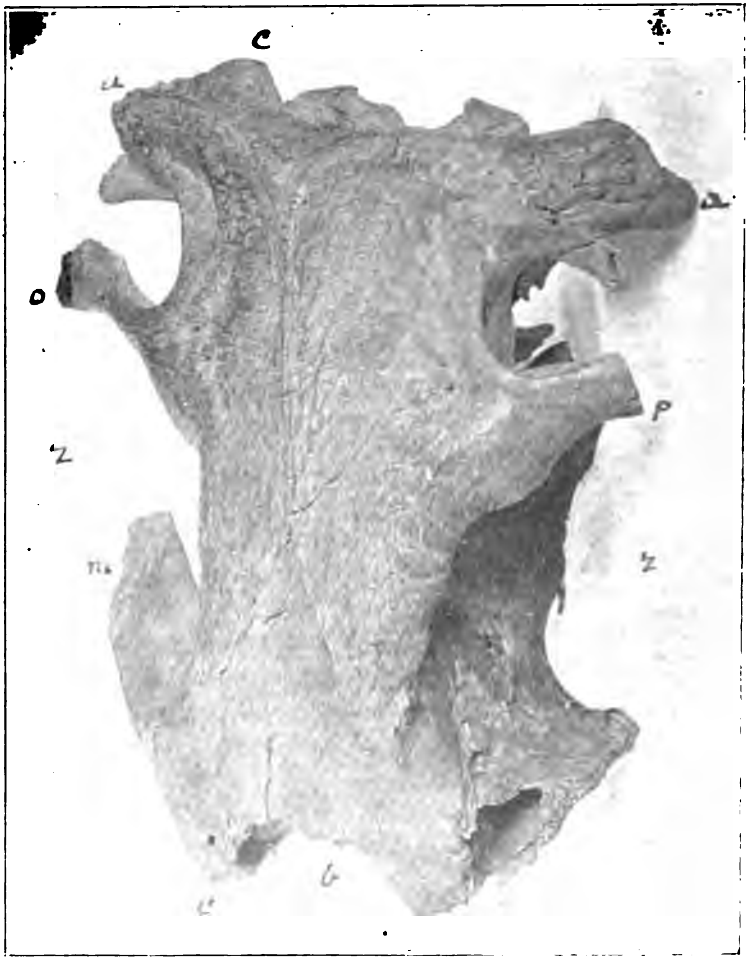


PLATE I.—FRONT AND UPPER VIEW.

From *c* to *c*, 9.25 inches.
From *a* to *a*, 7 inches.
From *o* to *p*, 7.6 inches.
From *z* to *z*, or from outer to outer of zygomatic arches, if restored, about 8.5 inches.
m.—Malar process to which anterior of zygoma was attached.
o.—Temporal process to which posterior of zygoma was attached.
b.—The border from which nasals were broken away.

PLATE II —POSTERIOR VIEW—ALSO UNDER SURFACE, MUCH FORESHORTENED.

pp. Pterygoid fossæ, caused by an inward bending of two thin, blade-like processes, making a double partition, thus closing up the middle of the postorior nares dividing it into an upper and a lower.

s. A straw entering the upper posterior nares.

t. A straw inserted in lower posterior nares.

oo. Outer to outer margins of occipital condyles, distance 2.6 inches.

gg. The four upper grinders, right side. Length of the series, *g* to *g*, 3.9 inches.

mm. Width of palate posteriorly, 2 inches. Lateral diameter of foramen magnum, 1.2 inches.

On the Waldron Fauna at Tarr Hole, Indiana.

By Edgar R. Cumings.

Perhaps no locality is more famous for its fossils, or better known to collectors than Waldron, Indiana. There is another locality, however, which, though less well known, promises to afford almost as rich a field for collecting. I refer to Tarr Hole, in Bartholomew County, Indiana.

This locality, though mentioned by Foerste and others of the Indiana Geological Survey, has never hitherto afforded an extensive list of fossils. Two years ago the present writer visited the locality in company with a student of the department of geology of Indiana University, and made a collection from which the following species have been identified. The bed is excavated each spring by the high water, the fossils being spread out over a sand spit, making their collection very easy. (The species are listed in the order of identification.)

1. Eucalyptocrinus (roots) (c).
2. Trematopora osculum *Hall* (rr).
3. Saginella elegans *Hall* (rr).
4. Trematopora infrequens *Hall* (rr).
5. Spirifer bicostatus var. petilus *Hall* (rr).
6. Chætetes consimilis *Hall* (r).
7. Lichenalia concentrica *Hall* (c).
8. Trematopora subimbricata *Hall* (rr).
9. Eucalyptocrinus cœlatus *Hall* (c).
10. Dalmanites verrucosus *Hall* (c).
11. Fenestella acmea *Hall* (rr).
12. Mytilarca sigilla *Hall* (rr).
13. Trematopora minuta *Hall* ? (rr).
14. Coelospira disparilis *Hall* (rr).
15. Spirifer radiatus *Sowerby* (rr).
16. Anastrophia internascens *Hall* (a).
17. Uncinulus stricklandi (*Sowerby*) *Hall and Clarke* (c).
18. Homœspira evax *Hall* (a).
19. Atrypa reticularis (*Linn.*) *Hall* (a)
20. Streptelasma radicans *Hall* (rr).
21. S. borealis *Nicholson* (rr).
22. Platystoma niagarense *Hall* (c).
23. Camarotœchia whitei *Hall* (aa).

24. Camarotœchia (?) neglecta *Hall* (a).
25. Camarotœchia (?) indianensis *Hall* (aa).
26. Camarotœchia (?) acinus *Hall* (r).
27. Meristina maria *Hall* (c).
28. Dalmanella elegantula *Hall* (c).
29. D. hybrida *Hall* (c).
30. Spirifer crispus (*Hisinger*) *Hall* (c).
31. ——— ——— var. simplex *Holl* (rr).
32. Leptæna rhomboidalis (*Wilckens*) *Hall and Clarke* (c).
33. Orthotetes subplanus (*Conrad*) *Hall and Clarke* (c).
34. Whitfieldella nitida *Hall* (a) (large form).
35. ——— ——— ——— (small form) (a).
36. Rhynchotreta cuneata var. americana *Hall* (a).
37. Dictyonella reticulata *Hall* (c).
38. Nucleospira pisiformis *Hall* (c).
39. Calymine niagarense *Hall* (r).
40. Eucalyptocrinus crassus *Hall* (rr).
41. Trematopora varia *Hall* (r).
42. Favosites forbesi var. occidentalis *Hall* (r).
43. Cornulites proprius *Hall* (rr).
44. Paleschara maculata *Hall* (rr) (on Camarotœchia indianensis).
45. Meristina rectirostris *Hall* (r).
46. Homœspira sobrina (*Beecher and Clarke*) *H. and C.* (rr).
47. Strophostylus cyclostomus *Hall* (rr).
48. ——— ——— ——— var. disjunctus *Hall* (rr).
49. Astylospongia præmosa *Goldfuss* (rr).
50. Spirifer cf. niagarensis *Hall* (rr).
51. Stropheodonta sp.
52. Modiolopsis perlata ? *Hall* (rr).
53. Paleschara (?) sphærion *Hall* (rr).
54. Rhodocrinus (lyriocrinus) Melissa *Hall* (rr).
55. Orthotetes subplanus ? (specimen 3.5 mm. long).
56. Lichas boltoni var. occidentalis *Hall* (rr).
57. Chonetes nova-scotica *Hall* (rr).
58. Lamellibranch cf. pterinea sp. .
59. Orthotetes tenuis *Hall* (rr).
60. Trematopora granulifera *Hall* (r).
61. Leperditia faba *Hall* (rr).

62. Homalonotus armatus *Hall* (rr).
63. Ceramopora labecula *Hall* (rr).
64. Stropheodonta profunda *Hall* (fragment).
65. Pholidops ovalis *Hall* (interior of ventral valve).
66. Fenistella parvulipora *Hall* (rr).
67. Strophiodonta striata *Hall* (rr).
68. Trematopora echinata *Hall* (rr).
69. Stephanocrinus (fragment).
70. Fistulipora maculata (*Hall*) (r).
71. Crania sp. (rr).

(The relative abundance of species in the above list is indicated by the letters in parentheses, aa indicating very abundant; a, abundant; c, common; r, rare, and rr, very rare.)

In the species Whitfieldella nitida no transitional forms were found between the large and small varieties, though a considerable number of specimens of both varieties were obtained.

The form given by Hall as Lichenalia concentrica var. maculata is here referred to the genus Fistulipora, since all the specimens from the present locality in which the maculæ are present, also possess mesopore apertures in the interapertural spaces, a character not possessed by Lichenalia as defined by Simpson. (See 14th Ann. Rept. State Geologist of N. Y., p. 559.)

The Stream Gradients of the Lower Mohawk Valley.

By Edgar R. Cumings.

During a recent study of the area mapped as the Amsterdam (N. Y.) sheet of the U. S. Geological Survey* the writer was struck by certain pecularities of the streams of this area emptying into the Mohawk River.

As will be seen by a reference to the accompanying map, practically all of these streams have a relatively flat gradient throughout their upper courses. The streams A, D and F have not cut through the glacial till that forms the beds of their lower courses, while all the streams A, D, E, F, G, H, flow over rock beds in their upper courses.

*The results of this study dealing with the stratigraphy and paleontology of the Lower Silurian formation will be published as a part of Bulletin No. 32 of the New York State Museum.

In all cases the upper courses are more mature, both as regards slope of the bed and with regard to steepness of banks and presence of waterfalls, etc.

The profiles to the right of the map are accurately drawn to scale from the data of the U. S. Topographic sheet. It will be seen that there is a remarkable uniformity in one particular, namely, the points (M, N) where the prolongations of the upper slopes intersect. A line coinciding with xy, the upper slopes of A and D, meets the prolongation of a line coinciding with EE′; the upper course of E, at M, and a line coinciding with the upper course of F (FN) meets the line coinciding with the upper courses of G and H (GG′, HH′) at N (nearly).

This state of affairs is not due to structure, for, as will be seen by the geologic sections (XY and W V), the formations and structure encountered by the several streams vary to a marked degree. G and H flow over hard, arenaceous limestone (Calciferous and Trenton in part)); F flows over the soft Utica shale; A flows over the even more yielding Hudson shales, and D and E over Utica. A and F are determined by a fault line. The lower courses, where not in glacial drift (F, D and A), are in limestone (G and H) and Utica shale (E).

There are three possible explanations of the peculiarity in question. (1) These mature upper gradients represent a period of base-leveling and subsequent elevation which has rejuvenated the streams, allowing them to re-excavate their beds; (2) the Mohawk Valley was plowed out to a depth of 240 to 260 feet by the Mohawk Valley glacier*; (3) the water of the Mohawk was dammed back to a level of 240 to 260 feet above the present river level for a length of time sufficient for the streams in question to mature.

Of these possible explanations the first is the more probable inasmuch as the stream, E, is manifestly preglacial and has been modified in its upper course to some extent by drift, nevertheless the upper gradient of this stream conforms distinctly to a river at a level of 500 feet (A. T.), instead of at a level of 240 feet as in the present Mohawk River. We must, therefore, believe that this stream reached grade before it was interfered with by the presence of the glacier.

As for the hypothesis of a plowing out of the Mohawk Valley, this seems hardly probable in view of the fact that the Hoffmans Ferry fault

*See Dana, A. J. S. (2) Vol. 35, pp. 243–249; Brigham, Bull. Geol. Soc. Amer., Vol. 9, pp. 183–210; Chamberlain, U. S. G. S. Third Ann. Rep., pp. 360–365.

offers a substantial barrier of hard limestone to such an amount of erosion on the part of the glacier. Furthermore, the gradients of the lower courses of some of the streams, at least, such as A, F and D, where the streams are still flowing through till must have been formed prior to the presence of the glacier since they are partly plugged with glacial debris. It seems likely, then, on the whole, that these streams had cut to grade not long prior to the glacial epoch and were rejuvenated together with the entire Mohawk system by the elevation which preceded or accompanied the glacial epoch.

Skull of Fossil Bison.

By W. G. Middleton and Joseph Moore.

Let it be said here, by way of introduction, that Mr. Middleton, of the Vincennes High School, as some members of the Academy will remember, obtained and reported to the late meeting the above-named specimen, reporting it as probably Bison latifrous, Leidy. Mr. Middleton gave his report verbally to the Academy, and has recently been in poor health, so that he has not been able to give it further study and write it up for publication. He, therefore, requests me (J. M.), since the specimen has been sent to Earlham College, to forward measurements, photographs and whatever notes may seem proper.

This cranium was found in 1896, a few miles from the city of Vincennes, Indiana, by a Mr. Brower. It was some six feet below the surface, partly unearthed by the caving in of the bank of a deep ditch.

It will be noted that what appears to be the horns are but the horn cores—processes of the frontal bones for the support of horns long since decayed. The horns, if restored, would add, say a foot to each projection.

	Ft.	*In.*
Distance from tip to tip of horn cores, direct line........	3	0 *
Circumference of horn cores near base................	1	0
From tip to tip of horn cores, line of outer curves.......	3	9
Width of forehead between horns.....................	1	3
Greatest width from outer to outer of orbit borders......	1	2½
Least width of forehead (between eyes and horns)......	1	½
Length of face from occipital crest to anterior of nasals..	1	9

* This measurement supposes an inch, more or less, to be restored to the tip of the right horn core, which has been broken off. Measurement as it appears in the cut is 35 inches.

Basal and Occipital View.

Front View.

Posterior View.

(It will be noted that the premaxillaries and a portion of the maxillaries are wanting With these restored the face would be six to eight inches longer.)

	Ft.	In.
Greatest width of occiput, right and left	1	½
Greatest width of occiputal condyles, right and left	0	5½

The horn cores at base are warty and spurred; throughout their length they are ridged and grooved.

A cross section of these cores at almost any point would give, approximately, a circle having an irregularly notched border.

The face is slightly depressed between the eyes, but the forehead above the eyes is moderately convex, both vertically and crosswise. This latter feature is the more marked immediately below the occipital crest.

The cranial cavity is perfect; so are the zygomatic arches. The maxillaries, as will be seen from photograph No. 2, are quite defective. The left maxillary has two fragmental grinders, second and third, numbering from behind.

We have called this a Fossil Bison, but the fact that it was found several feet below the surface does not, of itself, prove it to represent a species different from the ordinary recent (though almost extinct) "buffalo"—Bison bison. Remains of our recent bison have many times been found in peat, loam, loess and in ordinary marsh ground.

This specimen from Vincennes bears a close resemblance to the modern buffalo in many details, and yet it is evidently specifically different.

Prof. F. A. Lucas, of the U. S. National Museum, in his Memoir on the Fossil Bison of North America, describes the following six species—B. occidentalis, B. antiquus, B. crassicornis, B. alleni, B. ferox, and B. latifrons. This Vincennes specimen is *not* B. latifrons, as we suggested at the meeting of the Academy, as is clearly ascertained from further study and comparison.

From the size (and this is evidently a well-matured skull), from the length, diameter, direction, curvature and taper of the horn cores, we announce it, somewhat cautiously, as B. antiquus Leidy. In all of the above named particulars, and others we might name, it agrees much more nearly with said species than with our living bison.

Remains of B. antiquus have heretofore been found in two localities in California and at Big Bone Lick in Kentucky.

Fragments of fossil bison and allied forms have for a century, more or less, been called in a general way remains of a great American ox.

The accompanying plates, with the measurements, will aid the reader as to the size and form of the cranium we are studying. We are indebted to Prof. R. W. Barrett for photographs, also to Dr. J. Lindahl, of Cincinnati, for photographs of B. latifrons for comparison.

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PROCEEDINGS OF THE
INDIANA ACADEMY OF SCIENCE
1900

PROCEEDINGS

OF THE

Indiana Academy of Science

1900.

EDITOR, - - GEO. W. BENTON.

ASSOCIATE EDITORS:

C. A. WALDO,
C. H. EIGENMANN,
V. F. MARSTERS,
M. B. THOMAS,
W. A. NOYES,
STANLEY COULTER,
THOMAS GRAY,
JOHN S. WRIGHT.

INDIANAPOLIS, IND.

1901.

INDIANAPOLIS
WM. B. BURFORD, PRINTER
[illegible]

TABLE OF CONTENTS.

* Publication of the Proceedings of the Indiana Academy of Science began in 1891.

AN ACT TO PROVIDE FOR THE PUBLICATION OF THE REPORTS AND PAPERS OF THE INDIANA ACADEMY OF SCIENCE.

[Approved March 11, 1895.]

Preamble.

WHEREAS, The Indiana Academy of Science, a chartered scientific association, has embodied in its constitution a provision that it will, upon the request of the Governor, or of the several departments of the State government, through the Governor, and through its council as an advisory body, assist in the direction and execution of any investigation within its province, without pecuniary gain to the Academy, provided only that the necessary expenses of such investigation are borne by the State, and,

WHEREAS, The reports of the meetings of said Academy, with the several papers read before it, have very great educational, industrial and economic value, and should be preserved in permanent form, and,

WHEREAS, The Constitution of the State makes it the duty of the General Assembly to encourage by all suitable means intellectual, scientific and agricultural improvement, therefore,

Publication of the reports of the Indiana Academy of Science.

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana*, That hereafter the annual reports of the meetings of the Indiana Academy of Science, beginning with the report for the year 1894, including all papers of scientific or economic value, presented at such meetings, after they shall have been edited and prepared for publication as hereinafter provided, shall be published by and under the direction of the Commissioners of Public Printing and Binding.

Editing reports.

SEC. 2. Said reports shall be edited and prepared for publication without expense to the State, by a corps of editors to be selected and appointed by the Indiana Academy of Science, who shall not, by reason of such services, have any claim against the State for compensation. The form, style of binding, paper, typography and manner and extent of illustration of such reports, shall be determined by the editors, subject to the approval of the Commissioners of Public Printing and Stationery. Not less

Number of printed reports.

than 1,500 nor more than 3,000 copies of each of said reports shall be published, the size of the edition within said limits, to be determined by the concurrent action of the editors and the Commissioners of Public Printing and Stationery: *Provided*, That not to exceed six hundred dollars ($600) shall be expended for such publication in any one year, and not to extend beyond 1896: *Provided*, That no sums shall be deemed to be appropriated for the year 1894.

Proviso.

Disposition of reports.

SEC. 3. All except three hundred copies of each volume of said reports shall be placed in the custody of the State Librarian, who shall furnish one copy thereof to each public library in the State, one copy to each university, college or normal school in the State, one copy to each high school in the State having a library, which shall make application therefor, and one copy to such other institutions, societies or persons as may be designated by the Academy through its editors or its council. The remaining three hundred copies shall be turned over to the Academy to be disposed of as it may determine. In order to provide for the preservation of the same it shall be the duty of the Custodian of the State House to provide and place at the disposal of the Academy one of the unoccupied rooms of the State House, to be designated as the office of the Indiana Academy of Science, wherein said copies of said reports belonging to the Academy, together with the original manuscripts, drawings, etc., thereof can be safely kept, and he shall also equip the same with the necessary shelving and furniture.

Emergency.

SEC. 4. An emergency is hereby declared to exist for the immediate taking effect of this act, and it shall therefore take effect and be in force from and after its passage.

AN ACT FOR THE PROTECTION OF BIRDS, THEIR NESTS AND EGGS.

[Approved March 5, 1891.]

Birds.

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana*, That it shall be unlawful for any person to kill any wild bird other than a game bird, or purchase, offer for sale any such wild bird after it has been killed, or to destroy the nests or the eggs of any wild bird.

SEC. 2. For the purpose of this act the following shall be considered game birds: the Anatidæ, commonly called swans, geese, brant, and river and sea ducks; the Rallidæ, commonly known as rails, coots, mudhens, and gallinules; the Limicolæ, commonly known as shore birds, plovers, surf birds, snipe, woodcock and sandpipers, tattlers and curlews; the Gallinæ, commonly known as wild turkeys, grouse, prairie chickens, quail, and pheasants, all of which are not intended to be affected by this act. Game birds.

SEC. 3. Any person violating the provisions of Section 1 of this act shall, upon conviction, be fined in a sum not less than ten nor more than fifty dollars, to which may be added imprisonment for not less than five days nor more than thirty days. Penalty.

SEC. 4. Sections 1 and 2 of this act shall not apply to any person holding a permit giving the right to take birds or their nests and eggs for scientific purposes, as provided in Section 5 of this act. Permits.

SEC. 5. Permits may be granted by the Executive Board of the Indiana Academy of Science to any properly accredited person, permitting the holder thereof to collect birds, their nests or eggs for strictly scientific purposes. In order to obtain such permit the applicant for the same must present to said Board written testimonials from two well-known scientific men certifying to the good character and fitness of said applicant to be entrusted with such privilege and pay to said Board one dollar to defray the necessary expenses attending the granting of such permit, and must file with said Board a properly executed bond in the sum of two hundred dollars, signed by at least two responsible citizens of the State as sureties. The bond shall be forfeited to the State and the permit become void upon proof that the holder of such permit has killed any bird or taken the nests or eggs of any bird for any other purpose than that named in this section and shall further be subject for each offense to the penalties provided in this act. Permits to Science. Bond. Bond forfeited.

SEC. 6. The permits authorized by this act shall be in force for two years only from the date of their issue, and shall not be transferable. Two years.

SEC. 7. The English or European House Sparrow (Passer domesticus), crows, hawks, and other birds of prey are not included among the birds protected by this act. Birds of prey.

Acts repealed. SEC. 8. All acts or parts of acts heretofore passed in conflict with the provisions of this act are hereby repealed.

Emergency. SEC. 9. An emergency is declared to exist for the immediate taking effect of this act, therefore the same shall be in force and effect from and after its passage.

TAKING FISH FOR SCIENTIFIC PURPOSES.

Section 2, Chapter XXX, Acts of 1899, page 45, makes the following provision for the taking of fish for scientific purposes: "Provided, That in all cases of scientific observation he [the Commissioner of Fisheries and Game] shall require a permit from the Indiana Academy of Science."

OFFICERS, 1900-1901.

President,

MASON B. THOMAS.

Vice-President,

P. S. BAKER.

Secretary,

JOHN S. WRIGHT.

Assistant Secretary,

E. A. SCHULTZE.

Press Secretary,

GEO. W. BENTON.

Treasurer,

J. T. SCOVELL.

EXECUTIVE COMMITTEE.

M. B. Thomas,
P. S. Baker,
John S. Wright,
E. A. Schultze,
G. W. Benton,
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C. A. Waldo,
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Stanley Coulter,
Amos W. Butler,
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J. C. Arthur,
J. L. Campbell,
O. P. Hay,
T. C. Mendenhall,
John C. Branner,
J. P. D. John,
John M. Coulter,
David S. Jordan.

CURATORS.

BOTANY	J. C. Arthur.
ICHTHYOLOGY	C. H. Eigenmann.
HERPETOLOGY, MAMMALOGY, ORNITHOLOGY	Amos W. Butler.
ENTOMOLOGY	W. S. Blatchley.

COMMITTEES, 1900–1901.

PROGRAM.

R. J. Aley, Katherine Golden.

MEMBERSHIP.

A. W. Butler, M. J. Golden, Mel. T. Cook.

NOMINATIONS.

G. W. Benton, C. A. Waldo, M. E. Crowell.

AUDITING.

A. J. Bigney, E. E. Jones.

STATE LIBRARY.

A. W. Butler, Stanley Coulter, C. A. Waldo, J. S. Wright.

LEGISLATION FOR THE RESTRICTION OF WEEDS.

J. C. Arthur, Stanley Coulter, J. S. Wright.

PROPAGATION AND PROTECTION OF GAME AND FISH.

C. H. Eigenmann, A. W. Butler, W. S. Blatchley.

EDITOR.

Geo. W. Benton, 525 N. Pennsylvania St., Indianapolis.

DIRECTORS OF BIOLOGICAL SURVEY.

C. H. Eigenmann, V. F. Marsters, J. C. Arthur,
Donaldson Bodine, M. B. Thomas, Stanley Coulter.

RELATIONS OF THE ACADEMY TO THE STATE.

D. W. Dennis, A. W. Butler, R. W. McBride, G. W. Benton.

GRANTING PERMITS FOR COLLECTING BIRDS AND FISHES.

A. W. Butler, Stanley Coulter, W. S. Blatchley.

DISTRIBUTION OF THE PROCEEDINGS.

A. W. Butler, J. S. Wright, G. W. Benton.

OFFICERS OF THE INDIANA ACADEMY OF SCIENCE.

	President.	Secretary.	Asst. Secretary.	Press Secretary.	Treasurer.
1885–6	David S. Jordan	Amos W. Butler			O. P. Jenkins.
1886–7	John M. Coulter	Amos W. Butler			O. P. Jenkins.
1887–8	J. P. D. John	Amos W. Butler			O. P. Jenkins.
1888–9	John C. Branner	Amos W. Butler			O. P. Jenkins.
1889–90	T. C. Mendenhall	Amos W. Butler			O. P. Jenkins.
1890–1	O. P. Hay	Amos W. Butler			O. P. Jenkins.
1891–2	J. L. Campbell	Amos W. Butler			C. A. Waldo.
1892–3	J. C. Arthur	Amos W. Butler	Stanley Coulter. W. W. Norman.		C. A. Waldo.
1893–4	W. A. Noyes	C. A. Waldo	W. W. Norman		W. P. Shannon.
1894–5	A. W. Butler	John S. Wright	A. J. Bigney		W. P. Shannon.
1895–6	Stanley Coulter	John S. Wright	A. J. Bigney		W. P. Shannon.
1896–7	Thomas Gray	John S. Wright	A. J. Bigney		W. P. Shannon.
1897–8	C. A. Waldo	John S. Wright	A. J. Bigney	Geo. W. Benton	J. T. Scovell.
1898–9	C. H. Eigenmann	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.
1899–1900	D. W. Dennis	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.
1900–1901	M. B. Thomas	John S. Wright	E. A. Schultze	Geo. W. Benton	J. T. Scovell.

CONSTITUTION.

ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other resources and riches of the State; to arrange and prepare for publication such reports of investigation and discussions as may further the aims and objects of the Academy as set forth in these articles.

Whereas, the State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or of one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members or active members.

SEC. 2. Any person engaged in any department of scientific work, or in original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars, and there-

after an annual fee of one dollar. Any person who shall at one time contribute fifty dollars to the funds of this Academy, may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary, and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of this Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the

Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past Presidents, together with the officers and Executive Committee, shall constitute the Council of the Academy, and represent it in the transaction of any necessary business not specially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

MEMBERS.

FELLOWS.

R. J. Aley	*1898	Bloomington.
J. C. Arthur	1893	Lafayette.
P. S. Baker	1893	Greencastle.
George W. Benton	1896	Indianapolis.
A. J. Bigney	1897	Moore's Hill.
A. W. Bitting	1897	Lafayette.
Donaldson Bodine	1899	Crawfordsville.
W. S. Blatchley	1893	Indianapolis.
J. C. Branner	1893	Stanford University, Cal.
H. L. Bruner	1899	Irvington.
Wm. Lowe Bryan	1895	Bloomington.
Severance Burrage	1898	Lafayette.
A. W. Butler	1893	Indianapolis.
J. L. Campbell	1893	Crawfordsville.
John M. Coulter	1893	Chicago, Ill.
Stanley Coulter	1893	Lafayette.
Glenn Culbertson	1899	Hanover.
D. W. Dennis	1895	Richmond.
C. R. Dryer	1897	Terre Haute.
A. Wilmer Duff	1896	Worcester, Mass.
C. H. Eigenmann	1893	Bloomington.
A. L. Foley	1897	Bloomington.
Katherine E. Golden	1895	Lafayette.
M. J. Golden	1899	Lafayette.
W. F. M. Goss	1893	Lafayette.
Thomas Gray	1893	Terre Haute.
A. S. Hathaway	1895	Terre Haute.
O. P. Hay	1893	Washington, D. C.
Robert Hessler	1899	Logansport.
H. A. Huston	1893	Lafayette.
J. P. D. John	1893	Greencastle.
D. S. Jordan	1893	Stanford University, Cal.
Arthur Kendrick	1898	Terre Haute.
Robert E. Lyons	1896	Bloomington.
V. F. Marsters	1893	Bloomington.
C. L. Mees	1894	Terre Haute.
T. C. Mendenhall	1893	Worcester, Mass.
Joseph Moore	1896	Richmond.

* Date of election.

D. M. Mottier	*1893	Bloomington.
W. A. Noyes	1893	Terre Haute.
L. J. Rettger	1896	Terre Haute.
J. T. Scovell	1894	Terre Haute.
Alex. Smith	1893	Chicago, Ill.
W. E. Stone	1893	Lafayette.
Joseph Swain	1898	Bloomington.
M. B. Thomas	1893	Crawfordsville.
L. M. Underwood	1893	New York City.
C. A. Waldo	1893	Lafayette.
F. M. Webster	1894	Wooster, Ohio.
H. W. Wiley	1895	Washington, D. C.
John S. Wright	1894	Indianapolis.

NON-RESIDENT MEMBERS.

M. A. Brannon	Grand Forks, N. D.
D. H. Campbell	Stanford University, Cal.
B. W. Evermann	Washington, D. C.
Charles H. Gilbert	Stanford University, Cal.
C. W. Green	Stanford University, Cal.
C. W. Hargitt	Syracuse, N. Y.
Edward Hughes	Stockton, Cal.
O. P. Jenkins	Stanford University, Cal.
J. S. Kingsley	Tufts College, Mass.
D. T. MacDougal	Bronx Park, New York City.
Alfred Springer	Cincinnati, Ohio.
E. Vane Brumbaugh	Fayette, Iowa.
Robert B. Warder	Washington D. C.
Ernest Walker	Clemson College, S. C.

ACTIVE MEMBERS.

G. A. Abbott	Indianapolis.
Frederick W. Andrews	Bloomington.
George H. Ashley	Indianapolis.
George C. Ashman	Frankfort.
Edward Ayres	Lafayette.
Timothy H. Ball	Crown Point.
J. A. Bergström	Bloomington.

* Date of election.

Edwin M. Blake	Lafayette.
Lee F. Bennett	Valparaiso.
Charles S. Bond	Richmond.
M. C. Bradley	Bloomington.
Fred J. Breeze	Pittsburg.
O. W. Brown	Richmond.
A. Hugh Bryan	Indianapolis.
E. J. Chansler	Bicknell.
Walter W. Chipman	Warsaw.
Howard W. Clark	Culver.
George Clements	Crawfordsville.
Charles Clickener	Tangier.
Mel. T. Cook	Greencastle.
U. O. Cox	Mankato, Minn.
William Clifford Cox	Columbus.
Albert B. Crowe	Ft. Wayne.
M. E. Crowell	Franklin.
Will Cumback	Greensburg.
Edward Roscoe Cumings	Bloomington.
Alida M. Cunningham	Alexandria.
Lorenzo E. Daniels	Laporte.
Charles C. Deam	Bluffton.
Martha Doan	Westfield.
J. P. Dolan	Syracuse.
Herman B. Dorner	Lafayette.
Albert H. Douglass	Logansport.
Hans Duden	Indianapolis.
Joseph Eastman	Indianapolis.
E. G. Eberhardt	Indianapolis.
M. N. Elrod	Columbus.
Percy Norton Evans	Lafayette.
Samuel G. Evans	Evansville.
J. E. Ewers	
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Charles W. Garrett	Logansport.
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Vernon Gould	Rochester.
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Alden H. Hadley	Richmond.
U. S. Hanna	Bloomington.
William M. Heiney	Huntington.
Victor K. Hendricks	Terre Haute.

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J. A. Hill .... Peru.
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O. L. Kelso .... Terre Haute.
A. M. Kenyon .... Lafayette.
Ernest I. Kizer .... South Bend.
Charles T. Knipp .... Bloomington.
Thomas Large .... Madison, Wis.
John Levering .... Lafayette.
V. H. Lockwood .... Indianapolis.
William A. McBeth .... Terre Haute.
Robert Wesley McBride .... Indianapolis.
Rousseau McClellan .... Indianapolis.
Lynn B. McMullen .... Indianapolis.
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O. M. Meyncke .... Brookville.
W. G. Middleton .... Richmond.
John A. Miller .... Bloomington.
W. J. Moenkhaus .... Huntingburg.
H. T. Montgomery .... South Bend.
Walter P. Morgan .... Terre Haute.
J. P. Naylor .... Greencastle.
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John F. Newsom .... Stanford University, Cal.
E. W. Olive .... Indianapolis.
D. A. Owen .... Franklin.
Rollo J. Peirce .... Logansport.
W. H. Peirce .... Chicago, Ill.
Ralph B. Polk .... Greenwood.
James A. Price .... Ft. Wayne.
Frank A. Preston .... Indianapolis.
A. H. Purdue .... Fayetteville, Ark.
Ryland Ratliff .... Bloomington.
Claude Riddle .... Lafayette.

D. C. Ridgley	Chicago, Ill.
Curtis A. Rinson	Bloomington.
Giles E. Ripley	Decorah, Ia.
George L. Roberts	Greensburg.
D. A. Rothrock	Bloomington.
John F. Schnaible	Lafayette.
E. A. Schultze	Ft. Wayne.
John W. Shepherd	Terre Haute.
Claude Siebenthal	Indianapolis.
J. R. Slonaker	Bloomington.
Richard A. Smart	Lafayette.
Lillian Snyder	Rockville.
Retta E. Spears	Elkhart.
William Stewart	Lafayette.
J. M. Stoddard	Crawfordsville.
Charles F. Stegmaier	Greensburg.
William B. Streeter	Indianapolis.
Frank B. Taylor	Ft. Wayne.
S. N. Taylor	West Lafayette.
Erastus Test	Lafayette.
F. C. Test	Chicago, Ill.
J. F. Thompson	Richmond.
A. L. Treadwell	Oxford, Ohio.
Daniel J. Troyer	Goshen.
A. B. Ulrey	North Manchester.
W. B. Van Gorder	Worthington.
Arthur C. Veatch	Rockport.
H. S. Voorhees	Ft. Wayne.
J. H. Voris	Huntington.
Jacob Westlund	Lafayette.
Fred C. Whitcomb	Delphi.
William M. Whitten	South Bend.
Neil H. Williams	Indianapolis.
Guy Wilson	Greencastle.
Mae Woldt	Indianapolis.
William Watson Woollen	Indianapolis.
A. J. Woolman	Duluth, Minn.
J. F. Woolsey	Indianapolis.
A. C. Yoder	Vincennes.
O. B. Zell	Clinton.

Fellows	51
Nonresident members	14
Active members	137
Total	202

LIST OF FOREIGN CORRESPONDENTS.

AFRICA.

Dr. J. Medley Wood, Natal Botanical Gardens, Berea Durban, South Africa.

South African Philosophical Society, Cape Town, South Africa.

ASIA.

China Branch Royal Asiatic Society, Shanghai, China.

Asiatic Society of Bengal, Calcutta, India.

Geological Survey of India, Calcutta, India.

Indian Museum of India, Calcutta, India.

India Survey Department of India, Calcutta, India.

Deutsche Gesellschaft für Natur- und Völkerkunde Ostasiens, Tokio, Japan.

Imperial University, Tokio, Japan.

Koninklijke Naturkundige Vereeniging in Nederlandsch-Indie, Batavia, Java.

Hon. D. D. Baldwin, Honolulu, Hawaiian Islands.

EUROPE.

V. R. Tschusizu Schmidhoffen, Villa Tannenhof, Halle in Salzburg, Austria.

Herman von Vilas, Innsbruck, Austria.

Ethnologische Mittheilungen aus Ungarn, Budapest, Austro-Hungary.

Mathematische und Naturwissenschaftliche Berichte aus Ungarn, Budapest, Austro-Hungary.

K. K. Geologische Reichsanstalt, Vienna (Wien), Austro-Hungary.

K. U. Naturwissenschaftliche Gesellschaft, Budapest, Austro-Hungary.

Naturwissenschaftlich-Medizinischer Verein in Innsbruck (Tyrol), Austro-Hungary.

Editors "Termeszetrajzi Fuzetk," Hungarian National Museum, Budapest, Austro-Hungary.

Dr. Eugen Dadai, Adj. am Nat. Mus., Budapest, Austro-Hungary.

Dr. Julius von Madarasz, Budapest, Austro-Hungary.

K. K. Naturhistorisches Hofmuseum, Vienna (Wien), Austro-Hungary.

Ornithological Society of Vienna (Wien), Austro-Hungary.

Zoologische-Botanische Gesellschaft in Wien (Vienna), Austro-Hungary.

Dr. J. von Csato, Nagy Enyed, Austro-Hungary.

Malacological Society of Belgium, Brussels, Belgium.

Royal Academy of Science, Letters and Fine Arts, Brussels,, Belgium.

Royal Linnean Society, Brussels, Belgium.

Societé Belge de Geologie, de Paleontologié et Hydrologie, Brussels, Belgium.

Societé Royale de Botanique, Brussels, Belgium.

Societé Geologique de Belgique, Liège, Belgium.

Prof. Christian Frederick Lutken, Copenhagen, Denmark.

Bristol Naturalists' Society, Bristol, England.

Geological Society of London, London, England.

Dr. E. M. Holmes, British Pharm. Soc'y, Bloomsbury Sq., London, W. C., England.

Jenner Institute of Preventive Medicine, London, England.

Linnean Society of London, London, England.

Liverpool Geological Society, Liverpool, England.

Manchester Literary and Philosophical Society, Manchester, England.

"Nature," London, England.

Royal Botanical Society, London, England.

Royal Geological Society of Cornwall, Penzance, England.
Royal Microscopical Society, London, England.
Zoölogical Society, London, England.
Lieut.-Col. John Biddulph, 43 Charing Cross, London, England.
Dr. G. A. Boulenger, British Mus. (Nat. Hist.), London, England.
F. DuCane Godman, 10 Chandos St., Cavendish Sq., London, England.
Hon. E. L. Layard, Budleigh Salterton, Devonshire, England.
Mr. Osbert Salvin, Hawksford, Fernshurst, Haslemere, England.
Mr. Howard Saunders, 7 Radnor Place, Hyde Park, London W., England.
Phillip L. Sclater, 3 Hanover Sq., London W., England.
Dr. Richard Bowlder Sharpe, British Mus. (Nat. Hist.), London, England.
Prof. Alfred Russell Wallace, Corfe View, Parkstone, Dorset, England.

Botanical Society of France, Paris, France.
Ministérie de l'Agriculture, Paris, France.
Societé Entomologique de France, Paris, France.
L'Institut Grand Ducal de Luxembourg, Luxembourg, Lux., France.
Soc. de Horticulture et de Botan. de Marseille, Marseilles, France.
Societé Linneenne de Bordeaux, Bordeaux, France.
La Soc. Linneenne de Normandie, Caen, France.
Soc. des Naturelles, etc., Nantes, France.
Zoölogical Society of France, Paris, France.
Baron Louis d'Hamonville, Meurthe et Moselle, France.
Prof. Alphonse Milne-Edwards, Rue Cuvier, 57, Paris, France.
Pasteur Institute, Lille, France.

Bontanischer Verein der Provinz Brandenburg, Berlin, Germany.
Deutsche Geologische Gesellschaft, Berlin, Germany.
Entomologischer Verein in Berlin, Berlin, Germany.
Journal für Ornithologie, Berlin, Germany.
Prof. Dr. Jean Cabanis, Alte Jacob Strasse, 103 A., Berlin, Germany.
Augsburger Naturhistorischer Verein, Augsburg, Germany.
Count Hans von Berlspsen, Münden, Germany.
Braunschweiger Verein für Naturwissenschaft, Braunschweig, Germany.
Bremer Naturwissenschaftlicher Verein, Bremen, Germany.

Kaiserliche Leopoldische-Carolinische Deutsche Akademie der Naturforscher, Halle, Saxony, Germany.

Königlich-Sächsische Gesellschaft der Wissenschaften, Mathematisch-Physische Classe, Leipzig, Saxony, Germany.

Naturhistorische Gesellschaft zu Hanover, Hanover, Prussia, Germany.

Naturwissenschaftlicher Verein in Hamburg, Hamburg, Germany.

Verein für Erdkunde, Leipzig, Germany.

Verein für Naturkunde, Wiesbaden, Prussia.

Belfast Natural History and Philosophical Society, Belfast, Ireland.

Royal Dublin Society, Dublin.

Societa Entomologica Italiana, Florence, Italy.

Prof. H. H. Giglioli, Museum Vertebrate Zoölogy, Florence, Italy.

Dr. Alberto Perngia, Museo Civico di Storia Naturale, Genoa, Italy.

Societa Italiana de Scienze Naturali, Milan, Italy.

Societa Africana d' Italia, Naples, Italy.

Dell 'Academia Pontifico de Nuovi Lincei, Rome, Italy.

Minister of Agriculture, Industry and Commerce, Rome, Italy.

Rassegna della Scienze Geologiche in Italia, Rome, Italy.

R. Comitato Geologico d' Italia, Rome, Italy.

Prof. Count Tomasso Salvadori, Zoölog. Museum, Turin, Italy.

Royal Norwegian Society of Sciences, Throndhjem, Norway.

Dr. Robert Collett, Kongl. Frederiks Univ., Christiana, Norway.

Academia Real des Sciencias de Lisboa (Lisbon), Portugal.

Comité Geologique de Russie, St. Petersburg, Russia.

Imperial Academy of Sciences, St. Petersburg, Russia.

Imperial Society of Naturalists, Moscow, Russia.

The Botanical Society of Edinburgn, Edinburgh, Scotland.
John J. Dalgleish, Brankston Grange, Bogside Sta., Sterling, Scotland.
Edinburgh Geological Society, Edinburgh, Scotland.
Geological Society of Glasgow, Scotland.
John A. Harvie-Brown, Duniplace House, Larbert, Stirlingshire, Scotland.
Natural History Society, Glasgow, Scotland.
Philosophical Society of Glasgow, Glasgow, Scotland.
Royal Society of Edinburgh, Edinburgh, Scotland.
Royal Physical Society, Edinburgh, Scotland.

Barcelona Academia de Ciencias y Artes, Barcelona, Spain.
Royal Academy of Sciences, Madrid, Spain.

Institut Royal Geologique de Suède, Stockholm, Sweden.
Societé Entomologique à Stockholm, Stockholm, Sweden.
Royal Swedish Academy of Science, Stockholm, Sweden.

Naturforschende Gesellschaft, Basel, Switzerland.
Naturforschende Gesellschaft in Berne, Berne, Switzerland.
La Societé Botanique Suisse, Geneva, Switzerland.
Societé Helvetique de Sciences Naturelles, Geneva, Switzerland.
Societé de Physique et d' Historie Naturelle de Geneva, Geneva, Switzerland.
Concilium Bibliographicum, Zürich-Oberstrasse, Switzerland.
Naturforschende Gesellschaft, Zürich, Switzerland.
Schweizerische Botanische Gesellschaft, Zürich, Switzerland.
Prof. Herbert H. Field, Zürich, Switzerland.

AUSTRALIA.

Linnean Society of New South Wales, Sidney, New South Wales.
Royal Society of New South Wales, Sidney, New South Wales.
Prof. Liveridge, F. R. S., Sidney, New South Wales.

Hon. Minister of Mines, Sidney, New South Wales.
Mr. E. P. Ramsey, Sidney, New South Wales.
Royal Society of Queensland, Brisbane, Queensland.
Royal Society of South Australia, Adelaide, South Australia.
Victoria Pub. Library, Museum and Nat. Gallery, Melbourne, Victoria.
Prof. W. L. Buller, Wellington, New Zealand.

NORTH AMERICA.

Natural Hist. Society of British Columbia, Victoria, British Columbia.
Canadian Record of Science, Montreal, Canada.
McGill University, Montreal, Canada.
Natural Society, Montreal, Canada.
Natural History Society, St. Johns, New Brunswick.
Nova Scotia Institute of Science, Halifax, N. S.
Manitoba Historical and Scientific Society, Winnepeg, Manitoba.
Dr. T. McIlwraith, Cairnbrae, Hamilton, Ontario.
The Royal Society of Canada, Ottawa, Ontario.
Natural History Society, Toronto, Ontario.
Hamilton Association Library, Hamilton, Ontario.
Canadaian Entomologist, Ottawa, Ontario.
Department of Marine and Fisheries, Ottawa, Ontario.
Ontario Agricultural College, Guelph, Ontario.
Canadian Institute, Toronto.
Ottawa Field Naturalists' Club, Ottawa, Ontario.
University of Toronto, Toronto.
Geological Survey of Canada, Ottawa, Ontario.
La Naturàliste Canadian, Chicontini, Quebec.

La Naturale Za, City of Mexico.
Mexican Society of Natural History, City of Mexico.
Museo Nacional, City of Mexico.
Sociedad Cientifica Antonio Alzate, City of Mexico.
Sociedad Mexicana de Geographia y Estadistica de la Republica Mexicana, City of Mexico.

WEST INDIES.

Victoria Institute, Trinidad, British West Indies.

Museo Nacional, San Jose, Costa Rica, Central America.

Dr. Anastasia Alfaro, Secy. National Museum, San Jose, Costa Rica.

Rafael Arango, Havana, Cuba.

Jamaica Institute, Kingston, Jamaica, West Indies.

SOUTH AMERICA.

Argentina Historia Natural Florentine Amegline, Buenos Ayres, Argentine Republic.

Musée de la Plata, Argentine Republic.

Nacional Academia des Ciencias, Cordoba, Argentine Republic.

Sociedad Cientifica Argentina, Buenos Ayres.

Museo Nacional, Rio de Janeiro, Brazil.

Sociedad de Geographia, Rio de Janeiro, Brazil.

Dr. Herman von Jhering, Dir. Zoöl. Sec. Con. Geog. e Geol. de Sao Paulo, Rio Grande do Sul, Brazil.

Deutscher Wissenschaftlicher Verein in Santiago, Santiago, Chili.

Societé Scientifique du Chili, Santiago, Chili.

Sociedad Guatemalteca de Ciencias, Guatemala, Guatemala.

. . . PROGRAM . . .

OF THE

SIXTEENTH ANNUAL MEETING

OF THE

Indiana Academy of Science,

STATE HOUSE, INDIANAPOLIS.

December 26 and 27, 1900.

OFFICERS AND EX-OFFICIO EXECUTIVE COMMITTEE.

D. W. Dennis, President. M. B. Thomas, Vice-President. John S. Wright, Secretary.
E. A. Schultze, Asst. Secretary. Geo. W. Benton, Press Secretary.
J. T. Scovell, Treasurer.

C. H. Eigenmann,	Amos W. Butler,	O. P. Hay,	J. P. D. John,
C. A. Waldo,	W. A. Noyes,	T. C. Mendenhall,	John M. Coulter,
Thomas Gray,	J. C. Arthur,	John C. Branner,	David S. Jordan.
Stanley Coulter,	J. L. Campbell,		

The sessions of the Academy will be held in the State House, in the rooms of the State Board of Agriculture.

Headquarters will be at the Bates House. A rate of $2.00 and up per day will be made to all persons who make it known at the time of registering that they are members of the Academy.

Reduced railroad rates for the members can not be obtained under the present ruling of the Traffic Association. Many of the colleges can secure special rates on the various roads. Those who can not do this, could join the State Teachers' Association and thus secure a one and one-third round trip fare.

L. J. RETTGER,
SEVERANCE BURRAGE,
Committee.

GENERAL PROGRAM.

Wednesday, December 26.

Meeting of Executive Committee at the Hotel Headquarters .... 8 p. m.

Thursday, December 27.

General Session .... 9 a. m. to 12 m.
Sectional Meetings .... 2 p. m. to 5 p. m.

LIST OF PAPERS TO BE READ.

ADDRESS BY THE RETIRING PRESIDENT,

PROFESSOR DAVID W. DENNIS,

At 11 o'clock Thursday morning.

Subject: "Photomicrography as It May be Practiced To-Day."

The following papers will be read in the order in which they appear on the program, except that certain papers will be presented "*parri passu*" in sectional meetings. When a paper is called and the reader is not present, it will be dropped to the end of the list, unless by mutual agreement an exchange can be made with another whose time is approximately the same. Where no time was sent with the papers, they have been uniformly assigned ten minutes. Opportunity will be given after the reading of each paper for a brief discussion.

N. B.—By the order of the Academy, no paper can be read until an abstract of its contents or the written paper has been placed in the hands of the Secretary.

GENERAL.

1. The Leonids of 1900, 15 m........................John A. Miller.
2. Mosquitoes and Malaria, 10 m......................Robert Hessler.
*3. Outline of a Course of Reading on General Biological Problems, 10 m..................................C. H. Eigenmann.
4. A Shell Gorget Found near Spiceland, Ind., 10 m......Joseph Moore.
5. A Harbor at the South End of Lake Michigan, 15 m..J. L. Campbell.

MATHEMATICS AND PHYSICS.

6. Some Properties of the Symmedian Point, 8 m.......Robert J. Aley.
7. Note on McGinnis's Universial Solution, 5 m.........Robert J. Aley.
8. Graphic Methods in Elementary Mathematics, 10 m..Robert J. Aley.
9. The Automatic Temperature Regulator, 6 m......Charles T. Knipp.
*10. Concerning the Sphere as a Space-Element, 10 m....D. A. Rothrock.
11. The Cayleyan Cubic, 20 m........C. A. Waldo and John A. Newlin.
12. The Use of the Bicycle Wheel in Illustrating the Principles of the Gyroscope, 15 m.......................Charles T. Knipp.
13. The Cyclic Quadrilateral, 10 m........................J. C. Gregg.
14. Note on the Determination of Vapor Densities, 5 m., Charles T. Knipp.

***Author absent, paper not presented.**

15. An Improved Wehnelt Interrupter, 15 m., A. L. Foley and R. E. Nyswander.
16. A Method of Measuring the Absolute Dilatation of Mercury, 10 m .... A. L. Foley.
17. The Geodesic Line of the Space $ds^2=dx^2+\sin^2 x dy^2+dz^2$, 10 m .... S. C. Davisson.
18. The Friction of Railway Brake Shoes under Various Conditions of Speed, Pressure and Temperature, 10 m .... Richard A. Smart.
19. Diamond Fluorescence, 10 m .... A. L. Foley.
20. A Theorem in the Theory of Numbers, 10 .... Jacob Westlund.
21. On the Decomposition of Prime Numbers in a Bi-Quadratic Number-Field, 10 m .... Jacob Westlund.
22. Dissociation Potentials of Neutral Solutions of Lead Nitrate with Lead Peroxide Electrodes, 10 m... Arthur Kendrick.
23. Some Observations with Rayleigh's Alternate Current Phasemeter, 10 m .... E. S. Johonnott, Jr.

CHEMISTRY.

24. A Demonstration Apparatus, 10 m .... P. N. Evans.
25. Methylation of Halogenamides with Diazomethane, 10 m .... James H. Ransom.
26. Note on the Apparent Deterioration of Formalin, 2 m. Thomas Large.

BOTANY.

27. Notes on the Examination of Vegetable Powders, 10 m .... John S. Wright.
28. The Staining of Vegetable Powders, 5 m .... John S. Wright.
29. Cryptogamic Collections Made During the Year, 8 m.. M. B. Thomas.
30. Experiments with Smut, 8 m .... M. B. Thomas.
31. The Flora of Lake Maxinkuckee, 15 m .... J. T. Scovell.
32. Generic Nomenclature of the Cedar-Apples, 10 m .... J. C. Arthur.
*33. The Uredineae of Parke County, Indiana, 10 m .... Lillian Snyder.
34. Additions to the Flora of Indiana, 10 m .... Stanley Coulter.
*35. Seed Vitality in Native Plants, 10 m .... Stanley Coulter.

* Author absent, paper not presented.

36. Some Midsummer Plants of Southeastern Tennessee,
10 m .... Stanley Coulter.
37. A Study of the Constituents of Corn Smut, 10 m..... William Stuart.
38. A Bacterial Disease of Tomatoes, 10 m............. William Stuart.
39. Device for Supporting a Pasteur Flask, 3 m.... Katherine E. Golden.
40. Notes on the Microscopic Structure of Woods,
10 m .... Katherine E. Golden.
41. Movement of Protoplasm in the Hyphae of a
Mould, 10 m............................. Katherine E. Golden.
42. Description of Certain Bacteria Obtained from
Nodules of Various Leguminous Plants, 10 m. Severance Burrage.
43. A Few Mycological Notes for July and August, 1900
—Wells and Whitley Counties, 10 m........... E. B. Williamson.
*44. Notes on a Collection of the Fungi of Vigo County, 10 m.,
Fred Mutchler.

ZOOLOGY.

45. The Kankakee Salamander, 5 m....................... T. H. Ball.
46. The Eel Question and the Development of the Conger
Eel, 10 m.................................. C. H Eigenmann.
47. The Mounting of the Remains of Megalonyx Jeffersoni
from Henderson, Kentucky, 10 m............. C. H. Eigenmann.
48. Contribution Toward the Life History of the Squeteague, 10 m............................... C. H. Eigenmann.
49. A New Oceanic Fish, 10 m....................... C. H. Eigenmann.
49. A New Genus of Oceanic Fishes, 10 m............ C. H. Eigenmann.
50. A New Species of Cave Salamander from the Caves of
the Ozarks in Missouri, 10 m.................. C. H. Eigenmann.
51. An Addition to the Fishes Occurring in Indiana, 10 m.. L. J. Rettger.
*52. On the Function of the Blood-Sinuses of the Reptilian
Head, with Exhibition of Photographs, 10 m....... H. L. Bruner.
*53. Protraction of the Lower Jaw as a Means of Closing
the External Nares in Anura, 10 m................ H. L. Bruner.
*54. Some Interesting Peculiarities in the Development of
Hybrid Fishes, 15 m......................... W. J. Moenkhaus.

*Author absent, paper not presented.

*55. A Probable Hybrid Darter, 5 m..................W. J. Moenkhaus.
56. Some Observations of the Daily Habits of the Toad,
10 m ....J. R. Slonaker.
57. The Methods and Extent of the Illinois Ichthyological
Survey, 5 m....................................Thomas Large.
58. Additions to the Indiana Lists of Dragon-Flies, with a
Few Notes, 10 m............................E. B. Williamson.

GEOGRAPHY AND GEOLOGY.

59. Eskers and Esker Lakes, 20 m........................C. R. Dryer.
60. Spy Run and Poinsett Lake Bottoms, 7.,
J. A. Price and Albert Shaaf.
61. Abandoned Meanders of Spy Run Creek, 5 m.,
J. A. Price and Albert Shaaf.
62. The Development of the Wabash Drainage System and
the Recession of the Ice Sheet in Indiana, 20 m..Wm. A. McBeth.
63. A Theory to Explain the Western Indiana Bowlder
Belts, 5 m..................................Wm. A. McBeth.
64. Aids in Teaching Physical Geography, 10 m.........V. F. Marsters.
*65. Geography of Harper's Ferry Sheet (illustrated by
model), 10 m..................................V. F. Marsters.
66. River Bends and Bluffs, 10 m.....................Wm. M. Heiney.
67. Notes on the Ordovician Rocks of Southern Indiana,
10 m ....Edgar R. Cumings.
68. Some Developmental Stages of Orthothetes minutus
N. Sp., 10 m..............................Edgar R. Cumings.
†69. The Cold-Blooded Vertebrates of Winona Lake and Vicinity
......................................E. E. Ramsey.

* Author absent, paper not presented.

† The paper was announced in the program of 1899, but was not completed for publication until recently.

THE SIXTEENTH ANNUAL MEETING OF THE INDIANA ACADEMY OF SCIENCE.

The sixteenth annual meeting of the Indiana Academy of Science was held in Indianapolis, Thursday, December 27, 1900, preceded by a session of the Executive Committee of the Academy, 9 p. m., Wednesday, December 26.

At 9:15 a. m., December 27, President David W. Dennis called the Academy to order in general session, at which committees were appointed and other routine and miscellaneous business transacted. Following the disposition of the business, papers of general interest were read until 11 o'clock, at which time the retiring President, David W. Dennis, made his address: subject, "Photomicrography as It May Be Practiced To-Day."

At 2 p. m. the Academy met in two sections—biological and physico-chemical—for the reading and discussion of papers. President Dennis presided over the biological section, while Drs. J. L. Campbell and Thomas Gray in turn acted as chairman of the physico-chemical section. At 5 p. m. the section meetings adjourned and the Academy was assembled in general session for the transaction of business.

Adjournment, 5:30 p. m.

THE FIELD MEETING OF 1900.

The Field Meeting of 1900 was held in Terre Haute, Thursday, Friday and Saturday, May 24, 25 and 26.

Thursday evening members of the Executive Committee met in session at the Terre Haute House.

Friday was occupied by an excursion of the Academy to Alum Cave and vicinity. The party left Terre Haute by rail early in the morning, reaching Alum Cave about the middle of the forenoon, where the day was spent in visiting the mines and interesting coal fields of that vicinity. The return to Terre Haute was made in the evening. On Saturday excursions into the field were made in the neighborhood of Terre Haute.

The visiting members of the Academy gratefully acknowledge their indebtedness to the Terre Haute members, the members of the Terre Haute Science Club and their friends for the numerous thoughtful courtesies which made the Field Meeting of 1900 so pleasant and profitable.

PRESIDENT'S ADDRESS.

By D. W. Dennis.

Photomicrography as it May be Practiced To-Day.

The instrument with which my work in photomicrography is at present being done is in a compartment of the office of Dr. C. S. Bond, of Richmond, Indiana; it rests on a solid stone floor; the source of illumination is an arc light fed by a 52-volt alternating current. The tables, the optical bench, the microscope bench and all the illuminating accessories that it carries and the camera were furnished by the Bausch & Lomb Optical Company; the microscope stand and all its accessories were furnished by Zeiss; the stand is the 1899 model. The instrument is shown in Fig. 1. The objectives are the 70, 35, 16, 8, 4, and 2mm; the eyepieces are the 4, 6, and 8 compensating and the 4 projection eyepiece. The microscope stand is the property of the Earlham biological laboratory; all other parts, including the lenses, are the property of Dr. Bond, who not only by his financial assistance made it possible for me to have such an apparatus with which to work, but he has worked with me in all that I have done, and has carried out without regard to expense every suggestion that we could either of us make, with reference to the betterment of the instrument. The "we" which I use in my paper is not the conventional editor's we; it means the doctor and myself.

INTRODUCTORY.

The photomicrography of to-day at its best has been made possible by the growth of several different lines of work. The perfecting of the arc light is one of these; sunlight will do instead of this, but the uncertainty of being able to use it at any particular time is against it; the arc light is always ready; its brilliancy is always the same; photomicrographs of all diameters from 4,000 down can be made with it in from a very few minutes to a small fraction of one second. After one has fully mastered his apparatus and needs to use the light only for adjustment and exposure it is comparatively inexpensive.

The perfecting of the microscope in all its parts was necessary before the work of making photomicrographs of 1,000 diameters and upwards with such ease and certainty as to make them practicable for ordinary

purposes was possible. Indeed, the proper focusing of the microscope has been made so easy by Zeiss's latest stand that it may be said that only within a few months past has the use of these high powers been available except in the hands of the foremost experts, and even these consumed so much time and made so many failures to every success that a good photomicrograph was as costly as it was rare; an entire revolution of the micrometer adjustment screw in Zeiss's new 1899 model stand for photomicrography lifts or lowers the tube only .04 of a millimeter, i. e., one-fiftieth of the entire focal distance, and since a movement through less than one degree is entirely practicable, the tube of the microscope can be raised or lowered one nine-thousandth of a millimeter, or one two hundred and twenty-five thousandth of an inch. This is one eighteen thousandth of its focal distance.

How correctly to illuminate the object is again a science in itself; unless this is done, the most complete and costly apparatus constructible or imaginable will not give one correct photomicrograph; if the illumination is nearly right the results will be entirely wrong; the object can be drowned in light or it can be surrounded with halos that will remind the operator of a medieval painting without a suggestion of the piety that should accompany the reminder.

The production of a good photomicrograph requires a working knowledge of photography; the use of the right developer, the right plate, the proper use of reduction and intensification of the negative—all affect details. Three or at least two experts have hitherto been necessary for the production of a good photomicrograph of 2,000 or more diameters—a physicist to illuminate it, a microscopist with a knowledge of the object to adjust and focus the microscope, and a photographer to expose, develop and print it. The introductions to all atlases of this sort that I have seen show that the skill of several men has been enlisted in their production.

Photomicrography has grown then with the growth of microscopy, photography, and optics; it has proposed problems to all these sciences which they have separately taken up and solved in its behalf.

To retrace the steps from Daguerre to the end of the century, from Newton to Abbe, from the Dutch spectacle maker to Zeiss, is the work of books, not addresses; the sacrifices and victories along these journeys may have been elsewhere equaled, they have not been surpassed.

THE APPARATUS IN GENERAL.

The apparatus consists of a table 43 inches long and 15½ inches wide on strong and adjustable iron supports. Upon this table rests the optical bench on four adjustable iron legs which permit it to slide back and forth on two iron tracks. This optical bench carries the arc lights and all other accessories for illumination, except those which are a part of the microscope; these are, naming them from the light forward, first the condenser, which consists of two convexo-concave lenses four inches in diameter mounted at the ends of a nickeled tube; the lens farthest away from the light is adjustable in the carrying tube. Then comes the cooling cell, the ray filters, the shutter, the biconcave lens and the field diaphragm (see Fig. 1); all these parts are carried on two nickeled iron rods, and are adjustable in height from right to left and from before backward on the table. A second table placed at the end of this of the same width and height resting also on adjustable iron supports, is 85 inches long and carries the microscope, which has as substage parts the Abbe with its iris diaphragm and an additional iris diaphragm immediately under the object for use when the Abbe is swung out. It carries also an extensible camera which can be drawn out so as to hold the ground glass and the photographic plate at any distance from the object between 20 and 75 inches.

As to the Support of the Microscope.

It has hitherto been regarded as in principle wrong to have the microscope on the same table with the camera; our experience convinces me that this is a good arrangement, if it is accompanied by the other precautions we now have for keeping the microscope steady. As we received our instrument the microscope bench was clasped by iron clamps to two nickeled iron tubes which extend the entire length of the camera table and carry also the camera. By this arrangement any shaking of the camera was communicated to the microscope directly and rendered the preservation of the focus during the replacement of the ground glass by the plate holder nearly impossible; not one in five of our exposures with this arrangement was successful; something had to be done; we could not put the microscope on a separate table without entirely changing the means of controlling the fine adjustment, which is regulated by a rod, with milled head fastened to the table under the camera and connected

by a belt with the micrometer screw; furthermore, this exerted a slight pull on the microscope tube that rendered focusing very difficult; we overcame our difficulties by first placing four adjustable brass pillars under the microscope bench; the bench was now held down to the rods by the binding screws and its distance from the table was made absolutely the same by the brass supports; ordinary sliding of the camera in changing its length or putting in and taking out the plate holder does not in any way damage the focus. To brace the microscope tube against the pull of the focusing belt we supported it two and a half inches behind the milled head of the micrometer screw by an adjustable brass pillar reaching down to the camera table. Since making these additions we have not lost a single plate by change of focus. This result can be brought to pass in other ways, perhaps, but this is one good way and for the following reason is, I believe, the best way: We have fastened also to our camera table a brass rod inside of a brass tube, each provided at the focusing plate end of the camera with milled heads and at the microscope end with separate belts passing around the grooved heads that control the moveable stage, so that the operator six feet away can systematically search a field over, that is three-eighths of an inch in diameter. This is a convenience that comes near to being a necessity; it makes high power work as controllable and as speedy as low; it turns drudgery and annoyance into a pleasure; any one who ever undertook to center an object by giving directions to an assistant at the microscope must know its value. If an object is out of the field, finding it is hopeless in the old way; it is perhaps enough to say for our arrangement that it enables one person to do quickly and exactly what otherwise requires two at a cost of much time, labor and patience. The downward pull on the stage is counterbalanced by an adjustable brass support immediately under the controlling heads of the stage.

MAGNIFICATION.

The linear magnifications possible range from six and a half with the 70mm objective without an eyepiece to 5,500 with the 2mm objective and an 8 eyepiece. The following table shows the magnification at varying lengths of the camera with a few combinations. They were determined in every instance by measuring on the ground glass the projected image of a stage micrometer.

	Objective, 2 mm.			Objective, 4 mm.			Objective, 8 mm.			Objective, 16 mm.			Objective, 35 mm.			16 mm. Objective, Without Eyepiece.	70 mm. Objective, Without Eyepiece.
Camera extension, 25 inches	875	1250	1560	375	500	625	230	325	420	110	153	200	31	42	54	42	9½
Camera extension, 45 inches	1812	2560	3250	750	1062	1375	495	695	875	230	317	430	56	84	112	72	21
Camera extension, 65 inches	2750	3875	5000	1235	1625	2250	730	1062	1375	370	530	675	87	136	166	108	34
Eyepiece	4	6	8	4	6	8	4	6	8	4	6	8	4	6	8		

In will be seen by an inspection of the table that about 35 diameters can be obtained by using the 70mm lens and a camera extension of five and a half feet, or by using a 35mm lens and a 4 projection eyepiece with a camera extension of about 28 inches, or by using the 16mm lens and no eyepiece with a camera extension of 20 inches; each of these methods has of course its advantages, and disadvantages; the first gives a wider field than the last and a deeper focus. Fig. 3 was made in this manner; with the 16mm lens and no eyepiece only so much of the same object could be taken as lies between the points a and b in Fig. 3. The advantage this arrangement has to compensate for its smaller field and less deep focus is its greater resolving power; this principle holds whatever the combinations that produce any given power.

LEVELING.

The tables and the benches must all be exactly leveled; this is easily done by means of a spirit level and the adjustable feet on which they all rest. The cooling cell and condenser must also be level.

THE ILLUMINATION OF THE OBJECT.

(a) Centering.

It is necessary that all parts of this apparatus be most carefully centered. There are several good ways to do this. One is to place in every piece of the optical apparatus a pinhole diaphragm, which may be cut from black cardboard to fit each separate piece, one for the microscope to be substituted for the eyepiece, one for the Abbe and the field diaphragm, unless these parts are already provided with iris diaphragms, in which case they can be shut to a pinhole; one for the biconvex lens and one for the condenser. The instrument is sufficiently centered when a ray of light passes through this series of holes and falls on the center of the ground glass, when the camera is fully extended; these diaphragms should be saved so that proof of the centering can at any time be quickly made.

(b) The Image of the Light.

In order to make a good photomicrograph with an objective of 8mm focal length or less the image of the light should be thrown into the plane of the object. This can, the books say, "with no great difficulty," be effected by slipping the light and the condensing lenses back and forth

on the optical bench; it would be safer to say that it *can* be done; when once a combination has been effected that produces this result the exact position of every optical part should be noted carefully. To facilitate this all makers of photomicrographic apparatus would do well to mark a scale on the tables or on the carrying rods so that all parts can be quickly brought into exactly the same relation to each other and to the object; after many failures and much loss of time in attempting to bring the same state of things to pass that had been previously successful, we had such scales put on our apparatus. Any arrangement of the optical parts will produce an image somewhere; this can be found by carrying a piece of white paper back and forth in the path of the light until the image of the light is found; light and condensers can then be removed until the image rests in the plane of the object to be photographed. In order to have an equally illuminated field it is a good thing to have the size of the equally bright part of the image somewhat larger than the field to be taken; different combinations of the condensers and different positions of these and the light with reference to the object will regulate the size. In work with low powers, 16mm and upwards, this image should fall on the objective instead of the object. If the beginner in his hurry to spoil some plates is satisfied with an approximation to this state of things, or if he lights up and proceeds by the try rule, his time will be lost along with his material.

(c) THE SIZE OF THE ENTERING CONE OF LIGHT.

Three diaphragms should accompany every complete apparatus: One of these, the field diaphragm, should be placed near the double convex lens, and if possible on its microscope side. This must always be used in every exposure; a second is at the focus of the Abbe nearest the source of light, and need not be used when it is swung out; a third is brought on immediately under the object and is consequently open and not in use when the Abbe is; two of the three are accordingly required in every exposure, namely, the field diaphragm and the one before or the one behind the Abbe.

Only a careful study of the effect on the ground glass will avail in all cases for the regulation of these diaphragms. However, two valuable rules can be given: If the Abbe is not in use the diaphragm immediately under the object must be so closed as to cut off all but the field to be photographed; if the Abbe is being used its diaphragm must in general

be large enough for the cone of light entering through it to fill one-third of the central bright portion of the objective; to ascertain whether this is so or not one looks into the microscope tube when the eyepiece is in with a lens such as is often used for focusing on the ground glass; this must be done with every objective used with the Abbe and the exact point to which the diaphragm is opened should be observed on its graduated scale and recorded; if this is not done, and guesses are relied on, hit and miss (mostly miss) results need only be expected. Too wide a diaphragm will drown the details in light; too small a diaphragm will surround all details with diffraction halos that will gain in ugliness as one learns them better.

(d) Ray Filters.

The various colors of white light have differing values for optical and photo-chemical purposes; they do not focus after being refracted at the same place. When the apparatus is so adjusted that the red, orange and yellow rays which mainly affect the eye are in average focus on the ground glass, the blue and violet rays, which mainly affect the sensitive plate, will be in focus enough nearer the object to spoil the picture. One good way to overcome this difficulty is to use a color screen, which cuts out the red and orange rays and at the same time the blue, indigo and violet rays at the other end of the spectrum, leaving the yellow-green waves of approximately the same wave-length to affect both the eye and the plate; without this precaution a good photomicrograph can not be made with daylight or the electric arc; such a color screen is best produced by placing in the path of the light a glass trough with parallel sides and about three-sixteenths of an inch thick, filled with the following solution:

160 grams of dry, pure copper nitrate.
14 grams of pure chromic acid.
125 cc. of distilled water.

This is Zettnow's filter. We have found great advantage, especially in photographing preparations stained with saffrannin or fuchsine, in adding a second trough filled with a dilute solution of Loeffler's methylene blue.

FOCUSING ON THE GROUND GLASS.

Much has been written about the proper focusing of the object. Our experience leads me to conclude that the real difficulty has always been that the machinery of the microscope was not sufficiently accurate, its parts were not sufficiently firm relatively, the microscope itself was not sufficiently supported against damaging strains and jars, and its fine adjustment screw was not sufficiently fine; we need nothing but a fine ground glass and the unaided eye for correct focusing; a plate glass and a focusing lens are generally recommended; they are scarcely a help; the difficulty vanishes with such stable and delicate machinery as puts control entirely in the hands of the one focusing.

POSITION OF THE SENSITIVE PLATE.

A pure scarecrow of the books is the oft repeated necessity of having the sensitive plate take the exact place of the ground glass; some one must have concluded that a want of coincidence in this respect spoiled his plates, and other essay mongers must have copied the conclusions. Doubtless he and they had spoiled plates, but the cause was not here; a variation of a quarter of an inch makes a perceptible difference in magnification, but not in sharpness, and no instrument probably ever varied so much as this.

EXPOSURE.

The time of exposure depends on so many things it is not possible to give any rules: The source of the light, its intensity, the number and character of the condensers, the number and character of the color screens, the width of the diaphragms, the character of the object, the objective and eyepiece used, the sensitiveness of the plate, and the freshness and strength of the developer, all materially affect the time. Any one can find out the time necessary by a few trials provided he understands development and is a good judge of a negative. If he has not these accomplishments he never can tell. Some kind of shutter with which to accurately measure fractions of a second is so useful as almost to be necessary in getting the right exposure; placing a ground glass in the path of the light near its source will multiply the time of exposure some twenty-five times and would be necessary in the absence of a shutter.

PLATES.

It should go without saying, perhaps, that plates giving correct color values should generally be used. We have used Cramer's isochromatic mediums and Carbutt's orthochromatic mediums and have found them satisfactory.

CHEAP APPARATUS.

I can think of no valid plea for cheap apparatus. Some men with cheap apparatus can, to be sure, do better work than others with the costliest. The difference does not lie in the apparatus; this good work is, however, done at an outlay in time, patience and material that renders it so costly in the end as to be impracticable. This is why photomicrography has not been more used in the past. Makers of apparatus are careful to advertise "any microscope stand can be used." This, except for low power work of the simplest character and second grade in quality, is a delusion. Internal reflections from the microscope tube, the objective and its fastenings injure more or less everything; moreover, the trouble necessary to adjust a microscope every time work is wanted is by far the costliest part of the work; a special stand with a large tube from the walls of which reflection is impossible and into which properly constructed objectives can be screwed without a graduating series of collars, mounted firmly on an unshakable foundation, dedicated to this one use, always ready, quickly capable of adjustment for any practicable powers, with a source of light that does not require long-time exposures, immediately adjacent to a properly equipped dark room, is not only the cheapest arrangement; it is the only arrangement that will for any considerable time be used by a busy man. The complete apparatus as I have described it should be supplemented by a firm, permanent, upright stand for copying all such slides as will not permit the microscope to be brought to the horizontal position. This is one exception to my general proposition that cheap apparatus is too expensive. The exception is, however, only apparent, for this is as good an arrangement for this class of work as it will admit of. This sort of camera should be at hand in every laboratory where there is any one competent to use it, for the things for which it is necessary can neither be sent away nor can they await a more favorable hour often. Such apparatus in convenient form has been exhibited and described before this Academy.

LIMITATIONS.

Photography has its limitations. The time of exposure can not be accommodated to a field unequally illuminated. A man ten feet from the camera and a background of forest and hills from a hundred to a thousand feet away can not all be in correct focus at once. Undesirable and immaterial parts of the field will be taken with the same fidelity as the parts wanted. Photomicrography shares all these limitations. With skill they can be reduced to a minimum. By repeated exposures of the same field all parts wanted can be presented in correct focus and together in their true relationship. Fig. 5 was focused for the centrosome in the larger cell; Fig. 6 for the centrosome in the smaller cell. By the use of a special stage, objects can often be tilted so as to bring related points into the same plane. When one side of a field is lighter than the other something can be done by stopping the development at proper stages, washing the negative off and developing the exposed parts by a local application of the developer. Immaterial parts can be cut out by the application of a reducing agent to the negative or the positive, or by matting out in the process of printing. Much has been said against the use of reduction, intensification, retouching or even spotting out, and many inartistic, not to say ugly, prints have been made that might easily and without damage to fidelity have been made tolerable, if not beautiful. By the adjustment of the light, by the kind of light used, by the character of the developer, by the intensity of development, by the time of exposure and by the quality of the plate, two prints of the same object can be made to tell different tales. Photomicrography is not a means of compelling men to tell the truth; no such means has ever been discovered; the usual bounty for veracity is still to be had at the old stand. Clumsily practiced it tells nothing; it is reliable when the photomicrographer is both truthful and capable. There is no more reason why it should be compelled to tell immaterial stories while it is telling material ones than that any other witness on any other stand should be. I have, notwithstanding all this, always followed the rule never to cut out or reduce anything whatever from the material portion of the field. I have often hunted for hours to find a section free from defects which told exactly the same story that another one told, the defects of which I could have removed harmlessly and easily.

ADVANTAGES OF PHOTOMICROGRAPHY.

One great advantage of photomicrography is that it leads to the preparation of better microscopic slides, because, in part, of the rule that does not permit the negative to be altered in its material parts; in part also because the damaging defect can not always be removed. Another advantage is that when correctly carried out it can tell nothing but the truth with reference to the parts in focus. It is maintained by good authority that it sometimes reveals things not visible to ordinary vision. I have often seen things in photomicrographs that had escaped my attention before, but always when I came to observe carefully again I was able to see them. A skillfully prepared photomicrograph shows details more distinctly, with greater contrast, than they have when one observes them through the microscope; I see no reason why if the proper conditions were at hand it may not reveal details beyond the reach of ordinary microscopic vision. A sensitive plate is not blinded by light or tired with long looking. Photomicrography is not here presented as a remedy for all ills; drawings have certain advantages; but every one can not draw, and careful drawings require much more time than photomicrography. The best of both is had when the details of photomicrography are supplemented by a constructive diagram which uites all in one.

In science teaching photomicrography fills a place that nothing else can. Few people comparatively ever use the microscope to any educational purpose; probably not more than a tenth of the students in our colleges and universities are familiar with anything more than its simplest revelations; popular courses are wanted in and out of the colleges; psychology, pedagogy, child study, and all organic studies call for illustrations of biological laws or histological relationships which concern them; for most of them it is photomicrography, or drawings or both or nothing; and no one that has ever tried it will hesitate for a moment to say that the photomicrography must not be left out; it makes things real in a way that a diagram can not; it helps the interest, not indeed to the same extent that the microscope does, but to something like the same extent that the microscope would, if the student did not prepare his own object and if all the students could see the same thing at the same time through it and have the view explained while looking. I am sure that the histological lantern slide is with us to stay, and that the histological half-tone shortly will be.

KNOWLEDGE OF PHOTOGRAPHY.

Any one desiring to learn how to make good photomicrographs must procure a camera and learn how to make a good negative; it will not do for him to press the button and let some one else do the rest; he can not learn what a good negative is until he has made many and tested their printing qualities. When any one is a fair judge of the sort of lantern slide or print a negative will make he can then make a good one, and when he can at morning or at noon, on a clear or a cloudy day make a landscape negative and print it on glass or paper so well that his print compares favorably with the best of its class in the market, he may begin to experiment at photomicrography. He generally begins long before this and always produces and often publishes work that he never would have published could he have known what others were doing. Almost every photomicrographer has thrown away crop after crop of negatives which he formerly cherished as the best producible. At this stage he either quits or goes into a thorough study of the principles of photography on the simplest outdoor work; the production of high-power photomicrographs is the most difficult problem in photography and can only be done by good photographers who have had much experience also in low power work.

THE OBJECT TO BE PHOTOGRAPHED.

The photography of diatoms has flourished as a scientific fad for years. It is a special line of photography, calling for special illumination and specially prepared objectives; it calls for resolution, while general histological work requires penetration. It was for a long time a race with instrument makers to see which could resolve the finest striations; diatoms were used for test objects almost exclusively. It was gravely argued that a microscope that was good for diatoms was good also for other things in like proportion. Oblique illumination and blue light were praised for the same reason. The comfortless purchaser was left to reflect—having resolved a pleurosigma or an amphipleura—how few of them he ever cared to resolve, and that blue light concealed what he wanted to see. Every one easily admits, however, now that a diatom can be photographed; and since the publication of Koch's Bakterienkunde in 1889 and 1890 it has been granted that bacteria can be; they can be made to lies so uniformly in one plane. Doubtless it will always remain true that some things can be photographed better than others, and that

a good preparation is to be preferred for this purpose to a poor one, that only the best obtainable is to be photographed at all; but we are now in a position to photograph any object better than it is possible to see it by any single focusing of the microscope, and by repeated exposures any object can be photographed as well as it can be seen, so that all at least can be seen in the pictures that can be in the object. Fig. 7 is an egg from the ovary of a cat; the section is so thick that tissue cells lying behind it can be seen through it; and yet all is clear. It goes without saying that all the figures of the accompanying plates are of considerable thickness; one of them, Fig. 16, is an unsectioned blastula of Ascaris; the cavity within is seen through a cell which lies above it, and the light that illuminates it has passed through a cell that lies below, and yet the blastocoele is produced with almost diagramatic clearness.

WHAT THE NEXT STEP IN PHOTOMICROGRAPHY OUGHT TO BE.

The apparatus for the best work in photomicrography is very expensive and always will be. It requires and always will require an expert knowledge to make lantern slides and prints from microscopic preparations that an investigator can not afford to acquire and keep, and time that he could ill afford to spare. Education ought not to lack, it must not, will not lack this means of furthering its ends. We must establish here and there laboratories of photomicroscopy, in connection, preferably, with some of our institutions of learning, at which this work can be done for a considerable number of institutions. By this means negatives would accumulate from year to year until thousands of them might be at the command of all; the cost need not be great for all schools to possess slides of their own from this collection, or slides might be rented at a very small cost; all investigation monograms could thus be illustrated and teaching everywhere could be put in almost immediate touch with the latest that is known, and nothing else so vitalizes the work of the classroom, as every one knows who has tried it. I have tried to get slides from the plates used in works that had been published and copyrighted; I have never been able to do so; there was perhaps no means by which they could be easily made; there should be no other reason; they could only be used for teaching purposes; when one has harvested all the honor and money that can come from his publications I can not see why the good, that it does not impoverish him to part with should not be shared.

A scheme of this kind would furnish opportunity for friendly comparison of work which could not be other than a benefit. A half dozen such laboratories could do the work for the whole country; these could be affiliated and along this one line at least we should be spared the wastefulness of the anarchy of independent effort.

COURSE OF STUDY.

It would immediately come to pass in connection with such laboratories that courses of instruction would spring up. Such courses would be elected without doubt by many students in the various departments of botany and zoology, and as a result the ability to do good work would spread with the demand for it. One year's work in optics with special reference to photomicrography, microscopy and projection, one year in the theory and practice of photography, and two in the theory and practice of photomicrography would fill every requisite, whether of quantity or quality, from the beginning; it would be the work of experience to select finally what is just the best for such a course out of very much that is certainly good.

I have seen none of the literature of photomicrography of value except Neuhaus's "Lehrbuch der Microphotographie." Dr. Neuhaus is a practicing physician of Berlin. He has given us a work of such excellence that one does not need to see another; it contains a bibliography that probably leaves out little that has been written that is worth keeping. It should be translated into English. It was first published in 1890 and a second edition was called for in 1898. It is the first German work that has survived into a second edition.

EXPLANATION OF PLATES.

Except where otherwise stated the following figures have been made with a 2mm. apochromatic immersion objective and a 4 projection eyepiece with a camera extention of 37 inches and a magnification of 1,500. The slides, except where otherwise mentioned, were prepared by Mr. Elwood Mendenhall in the Earlham Biological Laboratory. The ascaris slides were stained by the iron-haematoxylin method. The material was fixed in Fleming's chrom-osmium-acetic fixative. The time of exposure was from 2 to 10 seconds. Zettnow's filter was used in each case, and for the Lilium candidum sections which were stained with saffranin, a Methylene blue filter in addition. No ground glass was used in any instance.

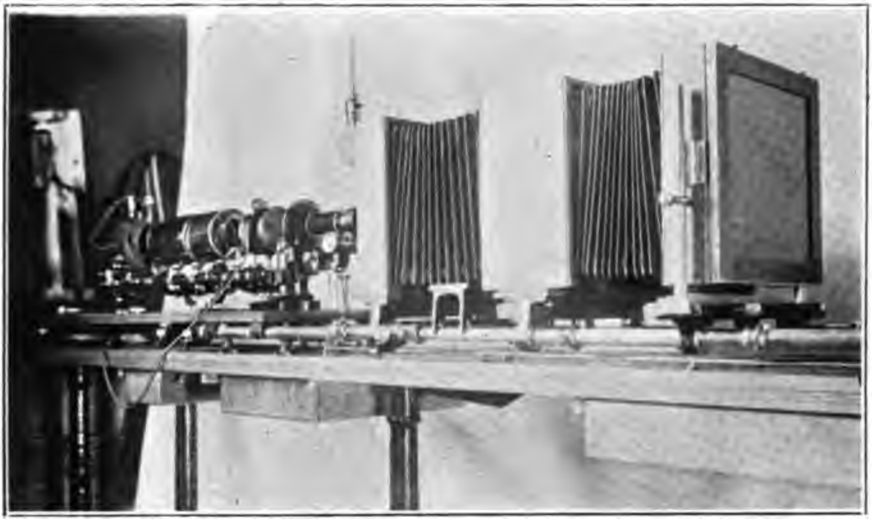

Fig. 1.

TONGUE OF SEA SNAIL.

Fig. 3. 70mm. objective, camera extension of 65 inches If same magnification had been obtained with 16mm. objective, the field would only have shown portion between *a* and *b*.

Fig. 5. Ascaris megalocephala, $\frac{1}{12}$ in objective and 4 projection eyepiece; focused for centrosome in larger cell.

Fig. 6. Same as fig. 5, except it is focused for centrosome in smaller cell.

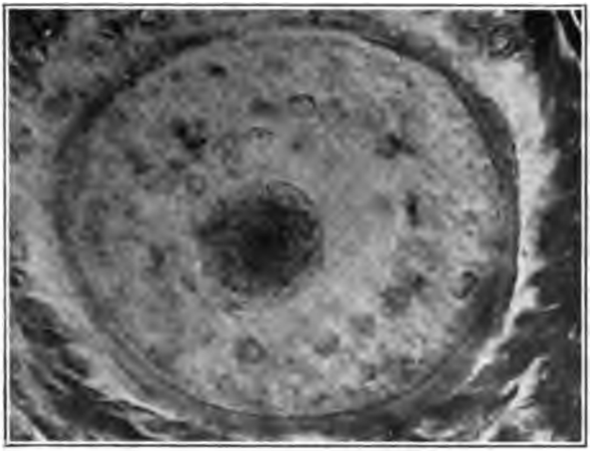

Fig. 7. Egg from the ovary of a cat, multiplied 1,500 times. Slide by Mr. Bertsch.

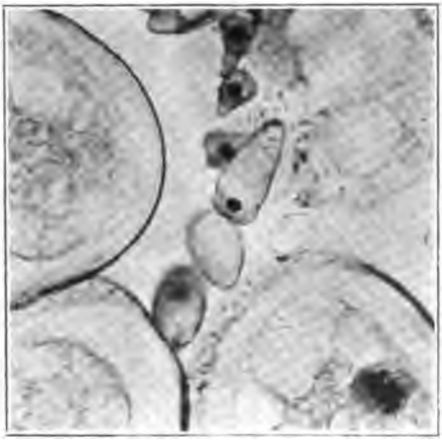

Fig. 8. Sperm cells of ascaris multiplied 825 times. 4mm. objective; 4 eyepiece.

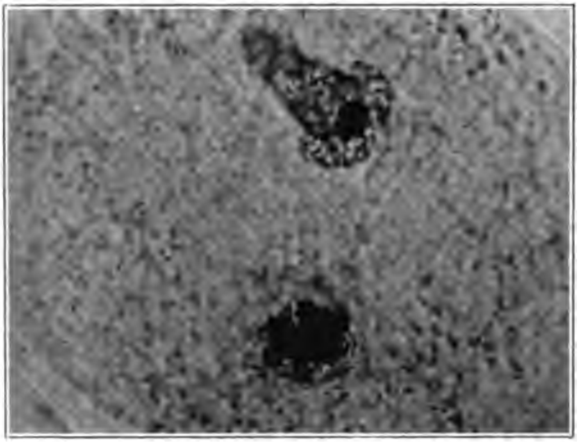

Fig. 9. The sperm cell is entering the egg from above; egg nucleus below multiplied 1,500 times.

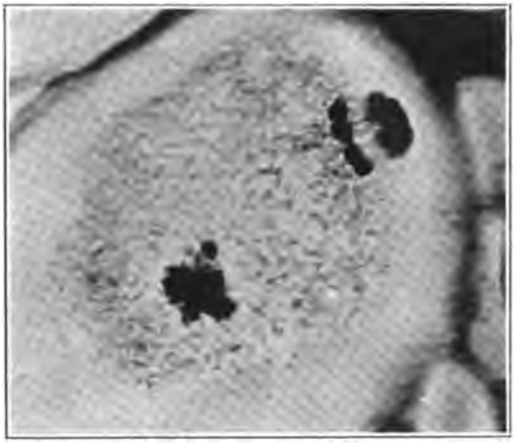

Fig. 10. The formation of the first polar body; sperm nucleus below. Slide by Mr. Irwin

Fig. 11. The mitotic figure is complete.

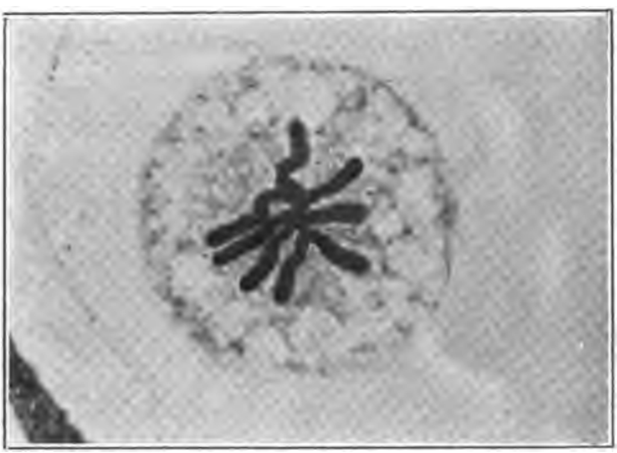

Fig. 12. Chromosomes of the equatorial plate seen from the pole.

Fig. 13. An early telophase; two centrosomes above; polar bodies outside of egg.

Fig. 14. A somewhat later phase; walls beginning to contract for two-cell stage.

Fig. 15. Two-cell stage.

Fig. 16. Blastula of ascaris, multiplied 1,500 times. The specimen is not sectioned; see text.

Fig. 17 Pollen mother cell of Lillium candidum; slide by Prof. David M. Mottier, multiplied 1,500 times.

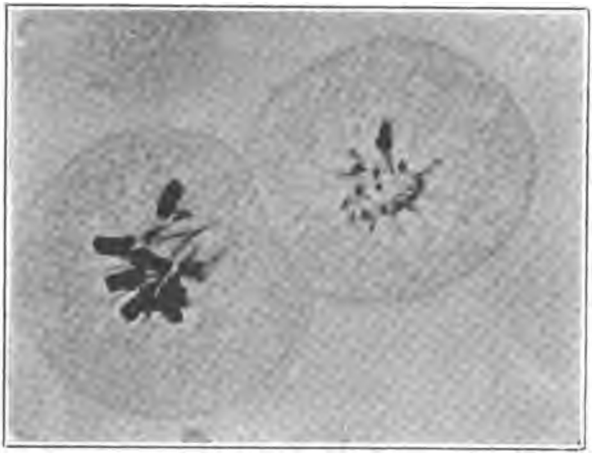

Fig. 18. L. candidum. The right-hand cell is cut at nearly right angles to plane of Fig. 17.

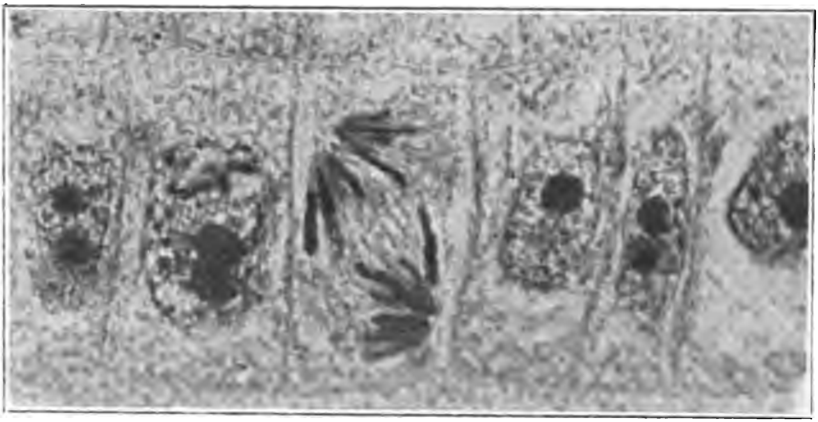

Fig. 19. Onion root; the oblique mitotic figure accommodates itself to the confined cell space.

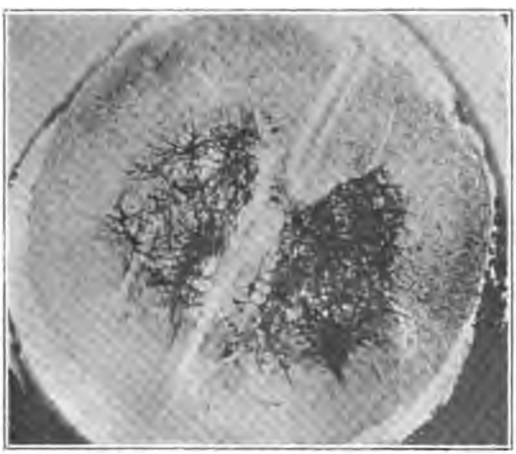

Fig. 20. Spinal cord of embryo pig, multiplied 50 times; Golgi preparation. Slide by Messrs. Warfel and Marshall.

Fig. 21. The upper left-hand cell of fig. 20, multiplied 200 times.

Fig. 22. The Commissure of fig. 20, multiplied 200 times.

The Leonids of 1900.

By John A. Miller.

The number of Leonids observed this year was very much smaller than was anticipated. Doubtless many escaped notice because of the bright moonshine and cloudy weather. Still, bearing these facts in mind, the shower was very disappointing. The *totale* of observations tend to confirm Dr. Johnstone Stoney's prediction that, owing to planetary perturbations, the stream bearing these meteors would not come nearer the earth this year than one and a half million miles.

On the mornings of November 14th and 15th my colleague, Mr. W. A. Cogshall, and myself, aided by our students, observed these meteors in order to obtain data concerning—

(a) The frequency of fall.

(b) The radiant.

(c) Duration of visibility; and

(d) The height at which the meteors appeared and disappeared.

On both mornings the sky was cloudy until three o'clock, and parts of it were overcast even after that time. Hence our observations for frequency are of small value. However, from 3:52 to 4:22 on the morning of the 14th our observers counted thirteen meteors. These came from the neighborhood of Leo, but were probably not all Leonids. At no other time were meteors so frequent as then. It was a source of remark, however, that they seemed to fall in groups two or three. That is, when one appeared one or two others followed at short intervals.

We attempted to obtain a sufficient number of trails of the meteors, photographically, to determine a radiant, but were unsuccessful. Our visual observations for the same purpose were more fruitful. On the morning of the 14th 45 meteor trails were platted; 13 of these were Leonids. On the morning of the 15th 41 were platted; 17 of which were Leonids. The radiant obtained from these paths was at the point whose right ascension is 149° and whose declination is 21°.

A Bergström chronoscope was employed to measure the duration of visibility. This instrument measures time accurately to the thousandth of a second, which is much less than the error introduced by the observer

in pressing the telegraphic key which registers the appearance and disappearance of the meteor. The average of the results obtained for the duration of visibility is 0.6 second.

In order to secure the parallax of the meteors observations were made at Bloomington and at Bedford. The co-ordinates of these stations are, for Bloomington, longitude 86° 32′ 11″, latitude 39° 10′; for Bedford, longitude 86° 39′ 10″, latitude 38° 52′. The distance (rectilinear) between the two stations is 33,652 meters, equaling 20.13 miles.

An examination of our charts and recorded times showed that of all the meteors platted only one had been observed simultaneously at both stations.

Using the method of Klinkerfues, we found that the height of the meteor at the time of apparition was 143 miles, and its height at the time of its disappearance was 64 miles.

Mosquitoes and Malaria.

By Robert Hessler.

[Abstract.]

The recently developed theory that mosquitoes are the carriers of malaria from one man to another, which is based on the definitely ascertained cause of malaria, is a question of considerable importance to inhabitants of malarial districts, such as we have, for instance, along the Wabash River.

Speaking of Indiana, especially when compared with former times, it may be said that malaria has lost its terrors. To see what the disease really is requires a visit to such a region as the desolate Roman Campagna, or to the Isthmus of Panama. The ravages of the disease, known about Rome as Pontine fever and at Panama as Chagras fever, is something terrible to contemplate.

Popularly it is generally believed that the drainage of wet areas and of stagnant waters is the cause for the great diminution in the number of cases and of its severity among us.

For a cause, biologists and physicians always want something tangible —a something that can be seen, felt, weighed or measured; a something

that appeals to the senses. Many persons are satisfied with a very simple explanation, and frequently a name suffices. The term "malaria" etymologically means "bad air," and was applied to the disease in olden times when bad air or a "miasm" was supposed to cause it.

Now what is malaria? we may ask. What is its cause? How does it get into the body?

Diseases due to a specific cause, to a living organism, spread about over the face of the earth just as we see animals and plants spread. Many with originally restricted habitats have in the course of time attained a world-wide distribution. Some diseases, natives of warm climates, periodically leave their natural boundaries, as yellow fever or cholera, flourish for a short time and then disappear utterly. If a new disease appears in a country and the conditions for its existence are favorable, then the disease remains and is called endemic. The cold of our winters has a destructive effect on many diseases and a retarding influence on others. Some flourish only during the warm months of the year.

The date when a new disease first appeared in a country, or rather an old disease in a new country, is accurately known in many instances, and the gradual spread after its introduction has been carefully followed in some cases. Leprosy, for instance, now so common in the Sandwich Islands, was brought in by the Chinese in 1840.

Malarial fever had a restricted habitat in former times and has gradually spread and still does spread to places where it had never been seen before. Its appearance and spread in the Island of Mauritius in comparatively recent years was attended with a frightful loss of life. It was brought into the island in 1866 by some sick sailors, and an epidemic followed; in the year 1867, 32,000 out of a population of 310,000 died of malaria. In some of the lowly situated districts more than one-fifth of the population perished from fever alone.

The original home of malaria is unknown. Many of the islands of the sea are still free from it. All other conditions may be favorable, but unless the active cause is introduced the disease never appears in a country where it had never been known to occur.

It is now about twenty years since Laveran, a French military surgeon, then stationed in Algiers, discovered and first described the active cause of malaria. This discovery has been verified again and again and is now universally recognized as the cause. It is a minute form

of life belonging to the sporozoa and is most commonly known under the name of Plasmodium malariae. To detect this parasite in the blood is the crucial test for malarial fever in these days of laboratory methods of investigating and diagnosing diseases; once found, the application of the remedy for the disease is clearly indicated—this is quinine or one of the alkaloids of the cinchona group. Quinine is a protoplasmic poison to the malarial parasite.

The Plasmodium malariae lives in and at the expense of the red blood corpuscles of human beings afflicted with the disease. It appears first as a minute speck in the corpuscles, gradually enlarges, and about the time the cell is consumed it undergoes a segmentation, each segment being a new and independent being which at once seeks a new host, a fresh corpuscle. Segmentation keeps up the species in the body of the host.

Under suitable conditions a higher development of the parasite can be seen. It is a process of differentiation into gametes, or males and females, and the resulting offspring are concerned in the transmission of the species, and of the disease, be it noted, into a new host.

The role of the mosquito in carrying the disease from one person to another has been worked out during the past two years. The prevailing view of how this is done may be outlined in this wise: When the Anopheles mosquito bites a human being afflicted with malaria, the parasites in the blood are taken into the insect's stomach and here and in the intestines they undergo a certain cycle of existence, or evolution, lasting about a week or ten days, and sporozoids—corresponding to the eggs of higher animals or to the seeds of plants—are formed, and these get into the salivary gland, and when the mosquito bites again they are, along with the saliva, injected into the wound. Once in the human system these sporozoa seek and occupy the red blood corpuscles; gradually they increase in numbers by sporulation, and in the course of a few days, or after one or more weeks, evidence of malaria manifests itself. In this way malaria is transmitted to a new individual.

The life history, or the development of the parasite, can be followed:

First. In the blood of a malaria fever patient by taking a drop of the blood at variable intervals and examining it under a high power of magnification. This will show the sporulating generation.

Second. In blood kept for some time under suitable conditions—warmth and loss of fluid by evaporation—under the microscope.

Third. In the organs, notably the spleen, of persons dying from malaria.

Fourth. In the bodies of mosquitoes after feeding on the blood of a malarial fever patient, the insects being kept at a summer heat.

With the cause definitely recognized, malarial fever may be defined in this wise:

"A specific infectious disease depending upon the presence in the blood of one or more of several species of closely allied parasites (Haemosporidia), which develop within, and at the expense of, the red blood corpuscle of the infected individual, resulting, according to the species and number of the parasites present, in more or less periodic febrile paroxysms or in continued fever."

We may now ask: How does this active cause get into the body? Or, in other words: How do we catch malaria?

When the mosquito theory was first announced it was thought that any and all mosquitoes could transmit the disease. It has since been found that there is only one genus which is now universally suspected.

There are about 250 species of mosquitoes described, and of this number about 30 have been found in the United States. The genus to which the malaria carrying mosquito belongs is that of Anopheles; it may be recognized by its spotted wings and the peculiar position of the body when at rest—the body axis projecting away from the place of support, as a wall. Our common mosquito belongs to the genus Culex and is considered harmless; it has no spots on the wings and the body axis at rest is parallel to the wall. Anopheles is an inhabitant of the country. Culex lives in the city as well as in the country.

Mosquitoes normally live on the juices of plants; the sucking of blood is an acquired habit. The females alone suck blood, the mouth-parts of the males are not adapted for it. They seem to survive our winters; they are often to be seen during warm days in the midwinter months. In the spring the few survivors are ready to repopulate all the country around—and at the same time spread malaria. With us malaria is essentially a disease of warm weather.

There are two chief methods by which the subject can be studied:

First. To search for Anopheles in its usual habitat and then for the malarial fever. Or,

Second. To find the malarial fever and then look for Anopheles.

The blood of man upon which the mosquito has been feeding can readily be studied in thin sections of the insect properly stained. In some of the slides which I will pass around, the distended stomach, filled with blood, can be easily distinguished; under a high magnification any Plasmodium malariae in the corpuscles can be seen.

From the preceding remarks it will be seen that three chief factors are involved in this question:

1. The fever-stricken human being, or, the disease in the body, or, in other words, the reaction brought about by the presence of the active cause.

2. The cause itself, the Plasmodium malariae.

3. The transmitting agent, carrying the active cause from one infected human being to others. This is the Anopheles mosquito.

Now what is to be said on the application of all these discovered facts? Most of us, unless we see a well defined application for newly discovered facts, are not inclined to attach any great importance to such discoveries, and, on the other hand, the more directly we are concerned the greater the value to us. In the field of medicine the value of a discovery is estimated in the light of the relief it gives mankind from disease and affliction.

How best to apply this new knowledge in reducing the ravages of malaria and in banishing it from the face of the earth is a question on which opinions differ. By some it is held that the best method of procedure is to destroy all the mosquitoes, and thus prevent the transmission from one individual to others. It is claimed by advocates of this class that the malarial parasite may not live exclusively in man, but might be inoculated from lower animals. On the other extreme are men who aim to exterminate malaria by exterminating the malaria germ itself, by properly diagnosing all malaria cases and administering sufficient quinine; by isolating all such patients and protecting them from mosquito bites. They blame the mosquito less than the infected blood upon which the insect feeds. It would be impossible, they argue, to get rid of all the mosquitoes in any community, much less of those in the whole world. Their reliance is quinine and screens.

Besides these extreme views there is what may be called a compromise, that is: To reduce the number of breeding places of the mosquito to a minimum, by drainage and drying up all wet places and pools of

stagnant water; by isolating the sick and protecting them from the bites and by the administration of quinine. With the breeding places reduced and the sick isolated there will be a constantly diminishing number of malarial fever cases.

A number of experiments have already been made along these lines. Former efforts, as those of the Italian government in planting Eucalyptus trees, have been futile because founded on imperfect data. Of the Eucalyptus it should, however, be said that it does have a slight influence, the leaves containing a volatile oil offensive to the mosquito, and on this account they do play a slight part in lessening the ravages of the disease among those living in a grove of the trees.*

Quite different are the results of experiments made this year. From the Eucalytus theory of a generation ago to the mosquito theory of to-day is a step far in advance, and results based thereon are equally significant.

The Italian railways—with their lonely stations in the plains and valleys—were the first to take advantage of the new theory in adopting prophylactic measures against mosquito infection of malaria by protecting their buildings and those occupied by their workmen by mosquito netting. The tests have been regarded as conclusive. Of 104 railway employes protected from mosquito infection not one contracted the disease. On the other hand, out of 359 persons not thus protected but otherwise living under similar conditions, only seven or eight escaped the fever.

A more elaborate test was made at Paestum, in a fearfully infected region to the southeast of Naples. The houses had wire screens over every opening—doors, windows, chimneys, etc., and persons going in and out after dusk were obliged to wear veils and closely woven, thick gloves. One hundred three persons were thus protected and of this number only three showed symptoms of malarial infection. The difficulty of inducing ignorant persons to fully comply with directions for protecting themselves accounts for the exceptions. No quinine was used by the party. Out of the population of 307 souls living in that region and not protected, all but five contracted malaria—these five being sons of the soil who seem to have been immune to a considerable extent. Where the protected party took no quinine, the exposed persons, on the other hand, during the same period, took six pounds.

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*The specimens of Eucalyptus here shown are, one from Battipaglia, north of Paestum, in a terribly devastated region of Italy; the other from the Roman Campagna above the Callistus catacombs.

It is now proposed to isolate all fever patients in the malarial districts and to protect the dwellings by screens—a tremendous undertaking with an area of 20,000 square miles and with a population, much of it very ignorant, of 2,500,000.

CHANGES IN INDIANA.

In regard to the changed condition in Indiana—the former prevalence of malaria, especially in the Wabash bottoms, even only two or three decades ago, and its comparative rarity at the present time: It seems to me that the explanation is to be sought chiefly in the fact that proper medication, the taking of sufficient quinine, is resorted to promptly nowadays, resulting in the rapid disappearance of the disease, or disease symptoms, in the afflicted individual, and thus keeping the number of foci from which the disease could be disseminated at a minimum, and at the same time shortening the period of existence of such foci, or, in other words: The fewer individuals there are in any neighborhood the less the liability for the healthy to contract the disease.

In former times quinine was a very costly remedy, used as a last resort and usually in insufficient doses; to-day quinine is very cheap and by many used for any suspicious malarial symptoms.

Then, too, mosquitoes were, no doubt, more abundant in former times than at present, owing to the greater number of wet places where the animals could breed; stagnant water being one of the essentials in the life history of the insect. Drainage is restricting such breeding places more and more, thus indirectly reducing the number of mosquitoes. Now that the proper relationship of malaria to swamps and pools is known, it becomes a comparatively easy matter to still further diminish the progeny of the "skeeters" still among us. The simplest method, except drying up wet places, is to spread a film of oil over all bodies of stagnant water—the larvae as they come to the surface to breathe get the oil in the respiratory system and quickly perish. The necessity of isolating and properly protecting all malarial fever cases is self-evident.

SUMMARY AND CONCLUSIONS.

Malaria is a disease which once had a restricted distribution, but which in the course of time has been distributed over the face of the earth; it is most common in warm climes; it is due to a specific cause,

the Plasmodium malariae, a minute organism living in and destroying the red blood corpuscles. The parasites are transmitted from one person to another by the mosquito. A certain cycle of the life history of the malarial parasite takes place within the body of the mosquito and the spores are injected from the salivary glands into and under the skin in biting.

Certain species of mosquitoes are the carriers to and fro of the infecting organisms. They may in a general way be recognized by their spotted wings and by their peculiar position when at rest.

The prevalence of malaria can be diminished by guarding against mosquito bites; by isolating malarial fever patients, giving them sufficient quinine and protecting them from being bitten; by reducing the number of breeding places of the mosquitoes by drainage.

Individual prophylaxis is best attained by avoiding the bite of the mosquito.

A Shell Gorget Found Near Spiceland, Indiana.

By Joseph Moore.

All I propose to do in this brief paper is to give a history of the object represented by the accompanying photograph, leaving it for others to tell the meaning of the engraved design and also its relation to other specimens of prehistoric art. About half a mile north of Spiceland, Henry County, while some men were loading gravel and sand, they came to some graves from which were taken two or three badly decayed human skeletons, the skull of a groundhog and the gorget which is the subject of this report. One of the human skulls is well preserved and the other sufficiently so to indicate its character. They represent rather a fine type of head.

The photograph herewith presented is very nearly one-half the size of the original, which is in length five and three-fourths inches. The greatest breadth toward the wider end is three and one-eighth inches, and that of the narrower end is two and one-half inches.

It has been wrought by dressing off the borders of a very large specimen of fresh water mussel, a species of Unio. It is evident both from the incompleteness of the original tracing on its concave surface and from the natural form of that species of shell that one-fourth, more or less, of the entire length of the original ornament has been broken off while yet in use, and the broken edge dressed to improve its appearance.

There are four perforations. As to the design, it has been engraved by a steady hand, and the fine grooves afterwards neatly stained with dark paint.

The photograph would probably represent the original somewhat more perfectly had not the finder varnished it, supposing it would otherwise be likely to crumble, as did the larger part of the two skeletons. It was, however, well preserved.

Professor Holmes of the Smithsonian Institute and Professor Warren K. Moorehead both regard it as an interesting find, and one or both of them will probably tell us more about what it is supposed to mean. So far as I have yet been able to learn, inscriptions on shell are more common further south, say in Tennessee and the Gulf States, than in the latitude of central Indiana.

This design is in some respects allied to what may occasionally be found among the ruins of Central America, judging from pictures observed in archeological reports.

I am indebted to David Newby of Spiceland for the specimen and to Professor Collins of Earlham for the photograph.

A Harbor at the South End of Lake Michigan.

BY J. L. CAMPBELL.

The northern boundary intended for Indiana by the act of Congress, July 13, 1787, and also the boundary designated in the act introduced December 27, 1815, by Mr. Jennings, the territorial delegate for the admission of Indiana as a State, was an east and west line through the southern extreme of Lake Michigan.

But an amendment to the original bill was adopted removing this boundary line ten miles to the north, and in this form the act was passed April 19, 1816.

This ten-mile line was marked on the early maps of the State, and has been the subject of curious inquiry by many who are ignorant of this item of State history.

By this amendment there was added to the territory of the State nearly one-half of the present counties of Steuben, Lagrange, Elkhart, St. Joseph and Laporte.

By the original line the State would have been cut off entirely from the great northern chain of lakes, and Michigan and Illinois would have cornered at the extreme southern limit of the lake.

The ten-mile strip gives to the State a lake front of forty miles between Michigan and Illinois, and makes Lake, Porter and Laporte counties parts of the border of our great inland sea.

I do not know who deserves the honor of securing the ten-mile strip, but I would be glad to erect two monuments to his memory, one where our shore line touches Illinois and the other to mark the line between this State and Michigan.

From the period of the admission of the State in 1816 until the present our wisest statesmen and best engineers have manifested great interest in the improvement of our lake front.

Michigan City was laid out in 1831, and in 1836 Congress made an appropriation of $20,000 for the beginning of a harbor at that place.

The site is a good one—the growth of the city has been satisfactory, a fair degree of liberality has been shown by the general government for the harbor, and the results prove that the expenditures have been wise.

It merits and should continue to receive the most generous support. But the new conditions around the head of Lake Michigan require im-

provements and advantages on a much greater scale than the continued support of a single harbor.

The village of 1830 at the mouth of Chicago River has become the second city of importance in the United States.

Its traffic by rail and water has become so great that relief and enlargement are most pressing, and these must be provided along the Indiana lake front.

The shore line along the lake is made up of loam and sand, which, although not the best material for harbor building, are of comparatively easy manipulation.

With other sites for a new harbor I ask attention anew to the mouth of the Calumet River, and particularly to the feasibility of using the strip of low land or lakelet east of the river and extending possibly into Porter County.

Between the sand hills or ridges, which are shown on the government survey, and the nearest railway line there is a strip of marsh land called, on the old maps, Long Lake.

If on examination it should be found practicable to dredge out this lake to the proper depth and connect it with the mouth of the Calumet the desired harbor would be easily constructed.

This site is specially commended on account of the protection afforded by the sand ridges on the north, thereby making it a haven as well as a harbor, and because it would interfere least with the railways along the lake shore.

The commercial advantages to the State are of the greatest importance.

All the railways running southeast and east from Chicago would use this new port for transfers between rail and water—and possibly also between railways west and north of Chicago on account of less expensive terminal facilities—so that the co-operation and support of the great railway interests would be secured.

Here would be the point of minimum cost between the Lake Superior iron ores and the block coal of central Indiana and the greatest stimulus offered to the development of all kinds of manufacturing industries.

The cheapening of transportation for oolitic limestone would be no small factor in favor of this new outlet.

Hammond and other flourishing cities in the northwest part of the State would experience the most direct benefits by the increase of business and manufacturing facilities and consequent increase in population.

The proposition is worth at least a passing thought and is commended to the State and general governments for further consideration.

Some Properties of the Symmedian Point.

By Robert J. Aley.

Monsieur Emile Lemoine, at the Lyons meeting of the French Association for the advancement of the Sciences in 1873, called attention to a particular point within the triangle, which he called the center of antiparallel medians. Since that time a number of mathematicians have studied the point and have discovered many of its properties. The point is such an interesting one that a brief collection of its more striking properties may be of some value. No claim is made to completeness.

DEFINITIONS OF THE POINT.

1. The point of concurrency of the bisectors of all lines antiparallel to the sides of the triangle.

2. The point of concurrency of the lines isogonal conjugate to the medians of the triangle; that is, the point of concurrency of the symmedians of the triangle.

3. The point within the triangle, the sum of the squares of whose distances from the three sides is the least possible.

4. The point within the triangle, whose distances from the sides is directly proportional to the sides.

NAMES OF THE POINT.

1. Center of antiparallel medians, proposed by Monsieur Emile Lemoine.

2. Symmedian point (symédiane, from symétrique de la médiane), proposed by Monsieur Maurice d'Ocagne. The English form "symmedian" was suggested by Mr. R. Tucker in 1884.

3. Minimum point, suggested by Dr. E. W. Grebe.
4. Grebe's point, proposed by Dr. A. Emmerich.
5. Lemoine's point, proposed by Professor J. Neuberg.

METHODS OF CONSTRUCTING THE POINT.

1. Draw the medians AM_a, BM_b of the triangle ABC. Then draw AK'_a, BK'_b, making the same angle with the bisectors of angles A and B, respectively, as are made by AM_a and BM_b. The intersection of AK'_a, BK'_b is K, the symmedian point.

2. Draw antiparallels to BC and CA. Join A and B, respectively, to the midpoints of these antiparallels, and the intersection of these joining lines is K, the symmedian point.

3. To the circumcircle of the triangle draw tangents at B, C and A, and let these intersect in X, Y, Z, respectively. Then AX, BY, CZ concur at K, the symmedian point.

SOME PROPERTIES OF THE POINT.

1. K is the point isogonal conjugate to G, the centroid.

2. If K_a, K_b, K_c are the feet of the perpendiculars from K to the three sides respectively, then

$$\left.\begin{aligned} KK_a &= \frac{2\triangle a}{a^2+b^2+c^2}. \\ KK_b &= \frac{2\triangle b}{a^2+b^2+c^2}. \\ KK_c &= \frac{2\triangle c}{a^2+b^2+c^2}. \end{aligned}\right\}$$ Where $\triangle$ is the area of the triangle ABC, and a, b, c are three sides of the same triangle.

3. $$\text{Area of } \triangle\, BKC = \frac{\triangle\, a^2}{a^2+b^2+c^2}$$

$$\text{Area of } \triangle\, CKA = \frac{\triangle\, b^2}{a^2+b^2+c^2}$$

$$\text{Area of } \triangle\, AKB = \frac{\triangle\, c^2}{a^2+b^2+c^2}$$

$$\triangle\, BKC : \triangle\, CKA : \triangle\, AKB = a^2 : b^2 : c^2.$$

4. Antiparallels to sides of the triangle through K are equal. Such antiparallels cut the sides of the triangle in six points which lie on a circle whose centre is K. This circle is called the *Cosine* Circle.

5. K is the median point of the triangle $K_aK_bK_c$.

6. The line KM_a (M_a is the mid point of BC) passes through the mid point of the altitude AH_a.

7. The sides of the K-pedal triangle $K_aK_bK_c$ are perpendicular to the medians of ABC, respectively.

8. The sides of the G-pedal triangle $G_aG_bG_c$ are perpendicular to the symmedians AK, BK, CK, respectively.

9. $a \cdot GA \cdot KA + b \cdot GB \cdot KB + C \cdot GC \cdot KC = a \cdot b \cdot c$.

10. If the symmedian lines AK, BK, CK meet the circumcircle of ABC in A', B', C', then the triangles ABC and $A'B'C'$ are co-symmedian, that is they have the same symmedian point K.

11. K and M (M is the circumcentre of ABC) are opposite ends of a diameter of Brocard's Circle.

12. Parallels to the sides of ABC through K, determine six points on the sides which lie on the Lemoine Circle.

13. If points A', B', C' be taken on KA, KB, KC so that $KA' : KB' : KC' = KA : KB : KC =$ constant, then antiparallels to the sides through A', B', C', respectively, determine six points on the sides of the triangle which lie on a Tucker Circle.

14. If $A_1 B_1 C_1$ is Brocard's first triangle, then

$A_1 K$ is parallel to BC.

$B_1 K$ is parallel to CA.

$C_1 K$ is parallel to AB.

15. AK, BK, CK produced meet Brocard's circle again in A'', B'', C'' respectively, and these points form Brocard's second triangle $A'' B'' C''$.

16. If KA, KB, KC, meet the sides of ABC in X_1, X_2, Y_1, Y_2 and Z_1, Z_2 respectively, then the sides of the triangle $Z_1 X_1 Y_1$ are parallel to $A\,\Omega$, $B\,\Omega$, $C\,\Omega$ respectively, and the sides of $Y_2 Z_2 X_2$ are parallel to $A\,\Omega'$, $B\,\Omega'$, $C\,\Omega'$ respectively, where Ω and Ω' are the Brocard points of ABC. Ω and K are the Brocard points of $Z_1X_1Y_1$ and Ω' and K are the Brocard points of $Y_2Z_2X_2$.

17. The point of concurrency D of AA_1, BB_1, CC_1 is the point isotomic conjugate to K.

18. The line MK is perpendicular to and bisects the line $\Omega\Omega'$.

19. The Simson line of Tarry's point is perpendicular to MK.

20. $\cot \angle KBC + \cot \angle KCA + \cot \angle KAB = 3 \cot \omega$ where ω is the Bocard angle.

21. If the symmedian AK cut BC in K'_a and the line MM_a in Q then (AK'_a, KQ) is a harmonic range.

22. If from K'_a perpendiculars p an q are drawn to CA, AB respectively, then

$$\frac{p}{b}=\frac{q}{c}=\frac{2\triangle}{a^2+b^2}$$

23. $AK:KK'_a=b^2+c^2:a^2$

24. $BK'_a:K'_a C=c^2:b^2$

$CK'_b:K'_b A=a^2:c^2$

$AK'_c:K'_c B=b^2:a^2$

$BK'_a=\frac{ac^2}{b^2+c^2}$ etc

25. The tangent to the circumcircle at A, and the symmedian AK are harmonic conjugates with respect to AB and AC.

26. The angles AMK, BMK, CMK are equal respectively to the angles (BC, B_1C_1) (AC, A_1C_1), (AB, A_1B_1), that is the respective angles between the sides of Brocard's first triangle and the corresponding sides of the fundamental triangle.

27. The sides of the $\triangle K_aK_bK_c$ are proportional to the medians of the $\triangle ABC$, and the angles of the $\triangle K_aK_bK_c$ are equal to the angles which the medians make with each other.

28. The sum of the squares of the sides of $K_aK_bK_c$ is less than the sum of the squares of the sides of any other triangle inscribed in ABC.

29. The ratio of the area of ABC to that of its co-symmedian triangle $A'B'C'$ (See No. 10) is $(-a^2+2b^2+2c^2)\ (2a^2-b^2+2c^2)\ (2a^2+2b^2-c^2):27a^2b^2c^2$.

Note On McGinnis's Universal Solution.

By Robert J. Aley.

The full title of the book is, "The Universal Solution for numerical and literal equations by which the roots of equations of all degrees can be expressed in terms of their coefficients, by M. A. McGinnis, Kansas City, Missouri, the Mathematical Book Company, 1900."

In his preface the author announces that the book appears at "the request of many able mathematicians, teachers and scholars throughout the United States." He also modestly states that the imaginary is for the first time put upon a true basis, that bi-quadratics are more thoroughly

treated than in any prior work and that it is the only work in which general equations beyond the fourth degree are solved. It is also the only book that shows the fallacies in Abel's proof that equations of higher degree than the fourth can not be solved by radicals.

That the book is interesting goes without saying. No one who promises so much can fail to write in an interesting manner. One follows breathlessly to see the kind of a paradox that will be produced.

A number of simple theorems in the theory of numbers and the theory of equations are stated as though they were new.

On page 53, article 164, we read: "The roots of quadratics represent the sides of *right triangles* when Real Quantities; the sides of *isosceles triangles* when *Real Imaginaries;* and when *Pure Imaginaries* may be represented by *lines.*" His argument for the latter part of the statement, it is needless to say, is not convincing.

A number of special numerical problems in equations of various degrees are solved. In many of these some very ingenious special methods are exhibited.

One chapter is devoted to the discussion of Wantzel's modification of Abel's proof of the impossibility of an algebraic solution of equations of higher degree than the fourth. The character of the discussion can be best understood by quoting the conclusion. "If we should accept his (Wantzel's) demonstration as true, we would be forced to the conclusion that the general equation of a degree higher than four was destitute of roots. The concluson of Wantzel that the roots can not be indicated in algebraical language is equivalent to saying that there are no roots, since it is absurd to say that finite quantities exist which can not be expressed in any function of other finite quantities, which are themselves symmetrical functions of the first, however complicated."

The author's notion of the imaginary is summed up in a general theorem, as follows: "An Imaginary Quantity is the indicated square root of the difference of the squares (with its sign changed) of the bases of two right triangles having a common perpendicular which is the radius of a circle; two of such triangles lying wholly within the semicircle, and two partly within and partly without the semicircle." What the theorem or the demonstration means would be hard to tell.

Of his so-called universal solution I will consider only that of the sixth degree. He assumes that—

$$x^6 - mx^5 - nx^4 - bx^3 - px^2 + tx - q = 0$$

$$\left(x^2 - \frac{m}{a}x - y\right)\left(x^2 - \frac{m}{b}x + z\right)\left(x^2 + \frac{m}{c}x + w\right) = 0$$

He then puts

$$(1) \quad n - \frac{m^2}{A} = \frac{A_0}{2m} - \frac{m^3}{2A^2} = y + z - x$$

$$(2) \quad p - \left(\frac{m^2n}{B^2} - \frac{m^4}{B^3}\right) = \frac{Bt}{m} = yz + yw - zw.$$

$$(3) \quad q = yzw$$

$$(4) \quad oA^3 - 2mnA^2 - 2m^3A - m^4 = 0$$

$$(5) \quad tB^4 - mpB^3 + m^3nB - m^5 = 0.$$

From (4 and 5) find A and B

Then x, y, z are found from 1, 2, 3 by means of a cubic equation.

The author incidentally remarks that the proper combination of the three values of A, and the four values of B are easily determined by a little practice. The author also says that it is evident that by comparing coefficients the values of 1/a, 1/b, 1/c can be obtained. The novice will find some difficulty in doing it. The real point of difficulty, however, is that we have eight unknown quantities, viz., a, b, c, x, y, z, A, B, and nine equations to be satisfied, viz., five by equating coefficients, and four from (1) and (2). So that the boasted solution is after all only a solution when there is some condition placed on the roots.

Graphic Methods in Elementary Mathematics.

By Robert J. Aley.

The Automatic Temperature Regulator.

By Chas. T. Knipp.

(Published in the Physical Review, Vol. XII, No 1, January, 1901.)

The Cayleyan Cubic.

By C. A. Waldo and John A. Newlin.

The Use of the Bicycle Wheel in Illustrating the Principles of the Gyroscope.

By Chas. T. Knipp.

(Published in the Physical Review, Vol. XII, No. 1, January, 1901.

The Cyclic Quadrilateral.

By J. C. Gregg.

PROBLEM.

The opposite sides of a quadrilateral FGHI inscribed in a circle, when produced, meet in P and Q; prove that the square of PQ is equal to the sum of the squares of the tangents from P and Q to the circle.—No. 80, page 470, Phillips and Fisher's Geometry.

SOLUTION.

(See Fig. I.)

On PO and QO as diameters draw circles (centers S and T) and cutting circle O in C, D, E and K. QK and PD are tangent to O. Through the points Q, F and G draw a circle cutting PQ in A. Then $\angle PHG = \angle GFI = \angle QAG$ $\therefore$ $\angle PAG$ is the supplement of $\angle PHG$ and PAGH is cyclic, and

$PQ.PA = PF.PG = \overline{PD}^2$ and

$PQ.QA = QH.QG = \overline{QK}^2$ and adding these two equations

$\overline{PQ}^2 = \overline{PD}^2 + \overline{QK}^2$ — Q. E. D.

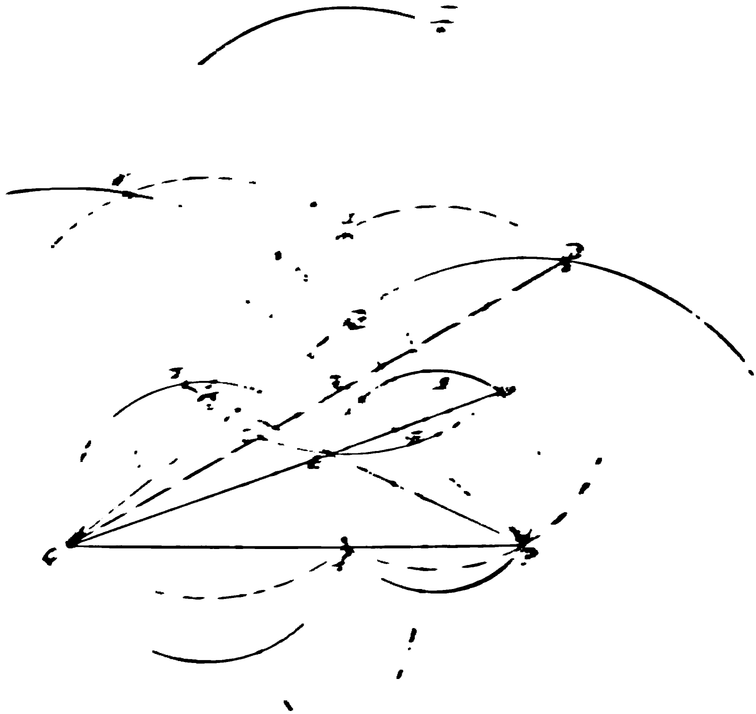


Fig. 1.

DISCUSSION.

(1) With P and Q as centers, and PD and QK as radii draw two arcs meeting in B. Then PBQ is a right angle, and PB is tangent to arc EBK, and as the tangents PD and PB to circle O and arc EBK are equal, P must be on the common chord KE produced: and in the same way DCQ is a straight line.

(2) Since PK.PE = PF.PG = PQ.PA, the point A is in the circumference T, and OA is perpendicular to PQ, and A is also in the circumference S.

(3) PQ.PA = PF.PG = PI.PH. ∴ the points A, Q, I, H are concyclic, and in the same way A, P, I, F are also concyclic.

(4) PK and QD are respectively perpendicular to QO and PO, and R is the orthocenter of the triangle POQ, and AO passes through R.

(5) The three arcs DEC, EBK and DBC cut orthogonally, two and two, and the common chord of any two of them passes through the center of the third.

(6) (See Fig. II.)

$\angle GPA + \angle GQA = \angle HIF$ (supplement of $\angle PGQ$).

$\angle GPH = \angle GAH.$

$\angle GQF = \angle GAF$ and adding these three equations

$\angle QPI + \angle PQI = \angle HAF + \angle HIF$, or

$180° - \angle HIF = \angle HAF + \angle HIF.$

$180° - 2\angle HIF = \angle HAF.$ But $\angle HOF = 2\angle HIF.$

$\therefore 180° - \angle HOF = \angle HAF$ and H, A, F, O, are concyclic.

(7) We have now shown the following points to be concyclic:

A, G, F, Q,—center M.
A, G, H, P,—center N.
A, O, K, Q,—center T.
A, P, D, O,—center S.
A, P, I, F,—center S′.
A, Q, I, H,—center T′.
A, H, O, F,—center O′.

And we will show that X is the center of a circle through A, G, O, I.

(8) CD, OA and HF are the three common chords of circles O, S and O′, and must meet in a point. Hence HF, the diagonal of FGHI, passes through R.

(9) Since APIF is cyclic $\angle QAF = \angle QIP$; and for the same reason $\angle PAH = \angle QIP$. $\therefore \angle QAF = \angle PAH$ and $\angle OAF = \angle OAH$.

(10) Since the circles S′, O′ and M pass through the points A and F, their centers S′, O′ and M are in the same line perpendicular to AF. For a similar reason N, O′, T′ are in the same line perpendicular to AH, and S′, S, N and T′, T, M are respectively in the same lines perpendicular to PQ or TS. Also T′S′, TS and MN respectively bisect AI, AO, and AG at right angles. Now the angles SO′S′ and SO′N have their sides respectively perpendicular to the sides of the equal angles OAF and OAH. $\therefore \angle SO'S' = \angle SO'N$ and $SN = SS'$, and in the same way $TM = TT'$. Hence the lines T′S′ and MN will meet TS at the same point X, and $XA = XG = XO = XI$ and X is the center of the circle through A, G, O, I.

(11) Now HF, OA, and GI are the three common chords of the circles O, O′ and X and must meet in a point. Hence GI the other

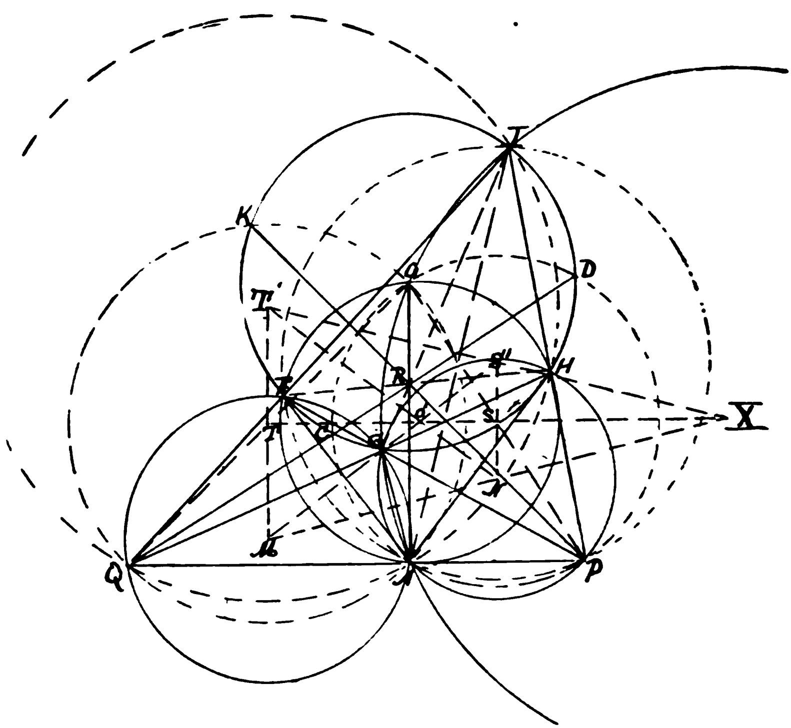


Fig II.

diagonal of FGHI also passes through R, and we have established the following

Theorem.—The diagonals of an inscribed quadrilateral meet in the orthocenter of the triangle whose vertices are the center of the circle, and the points where the opposite sides meet.

(12) (See Fig. 1.) Since QK, QE, PC and PD are tangents to circle O, the following theorem holds: If the diagonals of an inscribed quadrilateral meet in R, and its opposite sides meet in P and Q, and PR and QR be drawn cutting the circle in E, K, C and D, then PD, PC, QK and QE are tangent to the circle.

(13) The diagonals of *any* quadrilateral inscribed in circle O, and whose opposite sides meet in P and Q, will pass through R.

(14) If any point I, in circle O be joined to P and Q and cutting the circle in F and H, PF and QH will meet on the circumference as at G.

Note on the Determination of Vapor Densities.

By Chas. T. Knipp.

The object of this note is to describe briefly a method of determining vapor densities which was suggested to the writer last year while making observations on the surface tension of water at high temperatures.

The principle used is that the buoyancy of vapor increases as the density increases. An iron core *mn* (Fig. I), carrying a sphere *S* at its lower end is lifted by the sucking action of a coil in which a current is flowing. The lifting coil and core with sphere attached are contained in a steel vessel of sufficient strength to withstand high pressures. Three insulated circuits are run through the plug closing the vessel. The scheme

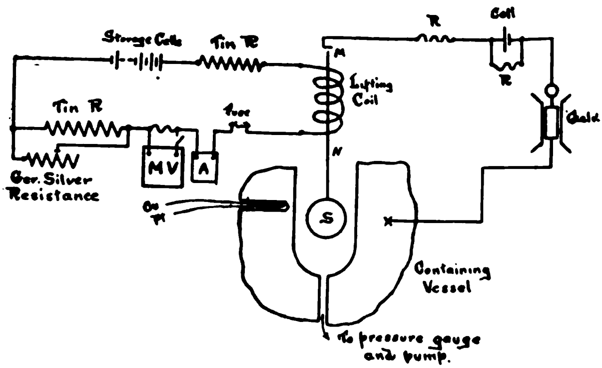


Fig. 1.

of connections is shown in Fig. I. The lifting current is supplied by a number of storage cells, the current being adjusted by tin resistances until the sphere is lifted. At that instant contact is made at *M*, closing the signal circuit, shown to the right in the figure. The temperature is read by means of a Cu-Pt thermo-junction. This is placed in a hole drilled in the containing vessel to within 2mm of the inner cavity. The vessel communicates with a pressure gauge and pump. The current required to lift the sphere is read by means of a milli-volt meter looped around a .03-ohm coil.

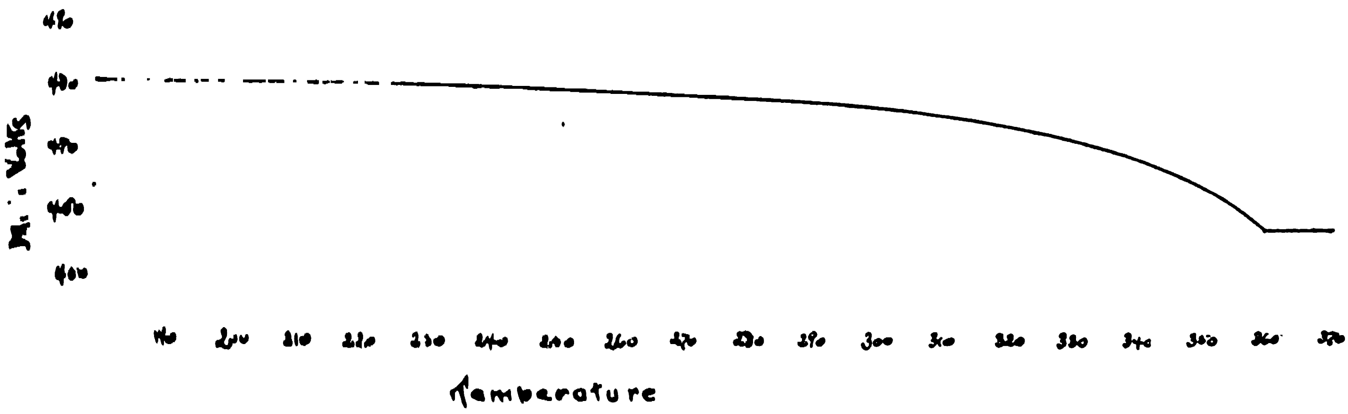


Fig. 2.

As yet only a few readings have been made, and these were obtained incidentally while conducting the investigation referred to above. A curve was platted (Fig. 2) in which temperatures are abscissas, and the corresponding currents are ordinates. Only the upper portion of the curve is shown in the figure. The density increases very slowly at first, and becomes constant when the critical temperature is passed.

This method furnishes a means of determining the critical temperature and critical pressure, as well as the critical volume of a liquid.

An Improved Wehnelt Interrupter.

[Abstract]

By Arthur L. Foley and R. E. Nyswander.

The chief difficulties encountered in working with the ordinary type of Wehnelt Interrupter are that the glass tube which holds the platinum wire is continually breaking and that the length and size of the projecting platinum wire can be changed only by constructing new tubes.

In the improved interrupter a lead vessel serves as electrode and to contain the electrolyte. The platinum wire is held in a brass tube having its lower end slotted and conical. A collar, sliding on the conical end, serves to press the jaws together and to clamp the platinum wire. The projecting end of the wire may be about 1 cm. long; the remainder of the wire may extend up the inside of the tube.

The lead vessel should be filled half full of the electrolyte and over this should be poured a layer of coal oil 2 or 3 cm. deep. The brass tube is gradually lowered until the platinum point extends to the desired depth in the electrolyte. The remainder of the platinum wire and the brass tube are entirely protected by the oil. The oil serves also to decrease the spray and fumes from the electrolyte. A platinum loop instead of a point is preferable in many cases. The action of the interrupter is made more constant.

Many other electrolytes may be used besides the usual 10 per cent. solution of sulphuric acid and water. As a matter of fact for high or low voltages some other electrolytes are superior. The following tables gives some data concerning a few of many electrolytes that have been used with this form of interrupter:

Solution (in water).	Voltage.	Spark.	Remarks.
1% sulphuric acid	40- 50	Short and thin	Fairly constant.
5% sulphuric acid	25 40	Short and thin	Fairly constant.
10% sulphuric acid	20 50	Strong	Fairly constant on high voltage.
20% sulphuric acid	20 80	Very strong	Unsteady. Will not work on high or low voltage
5% sulphuric acid 5% nitric acid	12 20	Average	Fairly constant.
5% caustic potash	40 50	Average	Stops frequently but, starts again without interruption.
10% sodium sulphite	75 115	Very heavy	Quite constant. High frequency. Used on 115 circuit without resistance.
10% sodium hyposulphite	40- 90	Strident	Ceases if short circuit is made on secondary.
10% acetic acid	....	....	Will not work on any voltage.
10% potassium sulphate	70 115	Average	Fairly constant.
10% ammonium nitrate	85 - 85	Strong	More constant if secondary short circuited.
10% potassium nitrate	90 115	Very heavy	Not constant when C" increased.
5% nitric acid (glass vessel and platinum sheet electrode).	30- 50	Strong and strident	Steady.

A Method of Measuring the Absolute Dilatation of Mercury.

[Abstract.]

By Arthur L. Foley.

The forms of apparatus used by Dulong and Petit, and Regnault, in determining the absolute dilatation of mercury are open to one or both of the following objections: (1) Some parts of the mercury columns are exposed and so the termperature can not be exactly the same throughout; (2) the heights of the columns must be measured from some assumed point of equilibrium in a horizontal connecting tube. The method proposed in this investigation is entirely free from both these objections.

The two arms of a vertical U tube are jacketed in the usual way, except that the jacketing tubes are of glass to permit the heights of the mercury columns to be taken with a cathetometer, at any level. Into the tube is poured a quantity of mercury sufficient to stand several centimeters high in each arm. When the required temperature has been attained the two heights are carefully measured. More mercury is added and under the same temperature conditions the heights are again measured. The differences in the heights before and after adding the mercury, together with the temperature difference of the two arms, are all the data required. Many independent determinations may be made by adding or removing mercury. As the readings are in every case difference readings any effects that might come from capillary and convection currents in the horizontal tube are eliminated. Two of my students, J. G. Gentry and O. A. Rawlins, have obtained remarkably consistent results by this method, though the coefficient of dilatation obtained by them is slightly less than that obtained by Regnault.

The Geodesic Line of the Space $ds^2 = dx^2 + \sin^2 x dy^2 + dz^2$.

By S. C. Davisson.

The Friction of Railway Brake Shoes Under Various Conditions of Pressure, Speed and Temperature.

By R. A. Smart.

Information concerning the friction of unlubricated rubbing surfaces is, unfortunately, limited in quantity, and it is believed that the data presented herewith, although relating particularly to the friction of brake shoes for railway cars, may be properly offered to the Academy as a contribution to the general subject.

The brake shoe is an important factor in the chain of mechanism popularly known as the air brake. It is not, strictly speaking, a part of the air brake, but is the immediate agent through which the air brake accomplishes the stopping of the train. It is the block of metal which is pressed against the tread of the car-wheel and which creates, in contact with the wheel, the friction which brings the wheel and hence the train to rest. It will at once be seen that the effectiveness of the whole air brake system on our railways is dependent directly upon the efficiency with which the brake shoe does its work. For instance, we can conceive of the brake shoe being made of some substance like glass, so hard that its friction would be practically nothing, in which case the air brake would be powerless to stop the train.

In fact, so important is the brake shoe in the eyes of railway officials that the Master Car Builders' Association has caused to be built an elaborate machine to be used exclusively for the testing of brake shoes. The need of such a machine will be understood when it is stated that the tendency of brake shoe manufacturers is, in order to be able to guarantee long life for their shoes, to make them so hard as to seriously impair their frictional qualities.

The Master Car Builders' Brake shoe testing machine, which has been deposited by them in the engineering laboratory of Purdue University, consists of a heavy revolving weight whose kinetic energy at any speed is equal to that of one-eighth of a loaded 60,000-pound freight car. On the same shaft as this weight and revolving with it is an ordinary car wheel. By a series of weighted levers, the shoe to be tested is pressed against the moving car wheel, thus bringing the wheel and, hence, the revolving weight to rest. When it is remembered that the freight car has eight wheels, each fitted with a brake shoe, it will be seen that the ma-

chine reproduces the conditions surrounding one-eighth of a freight car, so far as the forces involved in stopping the car are concerned. The machine provides a complicated recording mechanism by which the performance of the shoe while under test may be determined.

The present tests were undertaken to determine the effect upon the coefficient of friction of variations in three factors, viz.: The normal pressure between the shoe and the wheel, the speed of the wheel at the time the shoe is first applied, and the temperature of the rubbing surfaces. The effect of the first two variables was determined by making stops from various initial speeds and under different braking pressures, and calculating for each test the mean coefficient of friction for the stop. The limits of the variable elements under which the tests were made were as follows: Initial speed, 10 to 65 miles per hour; normal pressure, from about 2,800 pounds to about 10,700 pounds, these limits being the ones found in ordinary road service. In making a stop, the method of procedure is as follows: The weight and car wheel are brought to the desired speed of rotation by an engine. The engine is then disconnected from the revolving weight by a clutch and the brake shoe is brought in contact with the car wheel with the desired braking pressure. As the car wheel and weight are being brought to rest under the action of the brake shoe, the recording mechanism attached to the latter draws an autographic record of certain elements in the performance of the shoe, from which the mean coefficient of friction during the stop may be calculated.

The effect of the third variable mentioned above, namely, the temperature of the rubbing surfaces, was more difficult to determine. The temperature of the shoe only was observed, and this was found by imbedding in each end of the shoe the thermo-electric joint of a Le Chatelier pyrometer. This joint, in connection with a D'Arsonval galvonometer, gave continuous readings of the temperature of the face of the shoe near each end. The tests were made by making continuous runs at constant speed and noting simultaneously the temperature of the shoe and the coefficient of friction. The limits of temperature under which the tests were made were from about 60° F. to about 1500° F.

The results from the tests may be summed up as follows:

1. The coefficient of friction of brake shoes decreases with increase of pressure. The values are approximately as follows:

Soft cast-iron shoe.

Slow speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 37 per cent. to 20 per cent.

Soft cast-iron shoe.

High speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 25 per cent. to 15 per cent.

Hard cast-iron shoe.

Slow speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 33 per cent. to 18 per cent.

Hard cast-iron shoe.

High speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 17 per cent. to 12 per cent.

2. The coefficient of friction of brake shoes decreases with increase of initial speed. The values are approximately as follows:

Soft cast-iron shoe.

Light pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 37 per cent. to 25 per cent.

Soft cast-iron shoe.

Heavy pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 27 per cent. to 20 per cent.

Hard cast-iron shoe.

Light pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 33 per cent. to 20 per cent.

Hard cast-iron shoe.

Heavy pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 25 per cent. to 12 per cent.

3. The coefficient of friction of cast-iron brake shoes is practically constant with variations in temperature of shoe and wheel within the limits of the experiments.

Diamond Fluorescence.

[Abstract.]

By Arthur L. Foley.

A year ago I presented to the Academy an account of an experiment with a diamond and a photographic dry plate (Proceedings of Academy, 1899, p. 94). Later experiments have confirmed the theory presented. It has been found that a low temperature is favorable to the success of the experiment.

A Theorem in the Theory of Numbers.

By Jacob Westlund.

Let n be any prime number and let

$$S_k = 1^k + 2^k + 3^k + \ldots\ldots\ldots\ldots + (n-1^{k}.$$

Then

$S_k \equiv 0$, mod n, when $k \not\equiv 0$, mod $(n-1)$ and $S_k \equiv -1$, mod n, when $k \equiv 0$, mod $(n-1)$.

Proof. Consider the congruence.

$$x^{n-1} - 1 \equiv (x-1)\ (x-2) \ldots\ldots\ldots\ldots (x - \overline{n-1}), \text{ mod } n.$$

This congruence is evidently satisfied by the $n-1$ incongruent numbers.

$$1, 2, 3, \ldots\ldots\ldots\ldots\ldots\ldots (n-1).$$

But the congruence is of the degree $n-2$, since it may be written

$$+a_1 x^{n-2} - a_2 x^{n-3} + a_3 x^{n-4} \ldots\ldots\ldots\ldots - a_{n-1} - 1 \equiv 0, \text{ mod } n, \text{where}$$

$$a_1 = 1 + 2 + 3 + \ldots\ldots\ldots\ldots + (n-1)$$

$$a_2 = 1.2 + 1.3 + \ldots\ldots\ldots\ldots + 2.3 + \ldots\ldots\ldots\ldots$$

$$a_3 = 1.2.3 + 1.2.4 + \ldots\ldots\ldots\ldots$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$a_{n-1} = 1.2.3 \ldots\ldots\ldots\ldots (n-1).$$

Hence, since the number of roots of a congruence with prime modulus can not be greater than the modulus, the given congruence must be identical. Hence,

$$a_1 \equiv 0, \text{ mod } n.$$

$$a_2 \equiv 0, \text{ mod } n.$$

$$a_{n-2} \equiv 0, \text{ mod } n.$$

$$a_{n-1} \equiv 1, \text{ mod } n.$$

But from the theory of symmetric functions we have the following relations:

$$S_1 - a_1 = 0.$$

$$S_2 - S_1 a_1 + 2a_2 = 0.$$

$$\ldots\ldots\ldots\ldots\ldots\ldots$$

$$S_{n-2} - S_{n-3} a_1 + \ldots\ldots\ldots\ldots - (n-2) . a_{n-2} = 0.$$

$$S_{n-1} - S_{n-2} . a_1 + \ldots\ldots\ldots\ldots + (n-1) . a_{n-1} = 0.$$

$$S_n - S_{n-1} . a_1 + \ldots\ldots\ldots\ldots + S_1 . a_{n-1} = 0.$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Hence,

$S_1 \equiv 0$, mod. n.	$S_{2n-3} \equiv 0$ mod. n.
$S_2 \equiv 0$, mod. n.	$S_{2n-2} \equiv -1$ mod. n.
....	$S_{2n-1} \equiv 0$ mod. n.
$S_{n-2} \equiv 0$, mod. n.	....
$S_{n-1} \equiv \quad 1$ mod. n.	
$S_n \equiv 0$, mod. n.	
....	

or

$S_k \equiv 0$, mod n, when $k \not\equiv 0$ mod $(n-1)$ and $S_k \equiv -1$, mod n, when $k \equiv 0$ mod $(n-1)$.

On the Decomposition of Prime Numbers in a Biquadratic Number-Field.

By Jacob Westlund.

Let

$$x^4 + ax^2 + bx + c = 0$$

be an irreducible equation with integral co-efficients, whose discriminant $\triangle$ we suppose to be a prime number. Denote the roots of this equation by Θ, Θ', Θ'', Θ''', and let us consider the number-field $k(\Theta)$, generated by Θ. Then since the fundamental number of $k(\Theta)$ enters as a factor in the discriminant of every algebraic integer in $k(\Theta)$, it follows that $\triangle$ is the fundamental number of $k(\Theta)$ and

$$1,\ \Theta,\ \Theta^2,\ \Theta^3$$

form an integral basis, i. e., every algebraic integer α in $k(\Theta)$ can be written

$$\alpha = a_0 + a_1\Theta + a_2\Theta^2 + a_3\Theta^3$$

where a_0, a_1, a_2, a_3 are rational integers.

The decomposition of any rational prime p into its prime ideal factors is effected by means of the following theorem: If

$$F(x) = x^4 + ax^2 + bx + c$$

be resolved into its prime factors with respect to the modulus p and we have

$$F(x) \equiv \left\{ P_1(x) \right\}^{e_1} \left\{ P_2(x) \right\}^{e_2} \ldots\ldots (\mathrm{mod}\ p)$$

where $P_1(x)$, $P_2(x)$... are different prime functions with respect to p, of degrees f_1, f_2,... respectively, then

$$(p) = \left[p,\ P_1(\Theta) \right]^{e_1} \left[p,\ P_2(\Theta) \right]^{e_2} \ldots\ldots$$

where $\left[p,\ P_1(\Theta) \right]$, $\left[p,\ P_2(\Theta) \right]$ ..... are different prime ideals of degrees f_1, f_2,... respectively. (1)

In applying this theorem to the factorization of p we have two cases to consider, 1st when $p = \triangle$ and 2nd when $p \neq \triangle$.

Case I. $p = \triangle$.

Suppose

$$(p) = A_1^{e_1}\, A_2^{e_2}\, A_3^{e_3}\, A_4^{e_4}$$

where A_1, A_2 ... are different prime ideals of degrees f_1, f_2, ..., respectively. Then, since the fundamental number of $k(\Theta)$ is divisible by $p^{f_1(e_1 - 1) + f_2(e_2 - 1) + \cdots}$ (1), we have

$$f_1(e_1 - 1) + f_2(e_2 - 1) + f_3(e_3 - 1) + f_4(e_4 - 1) = 1,$$

(1) Hilbert: "Bericht über die Theorie der Algebraischen Zahlkörper," Jahresbericht der Deutschen Mathematiker-Vereinigung (1894-95), pp. 198, 202.

and also

$$[illegible] = 4$$

From these two [illegible] we see, remembering that [illegible] is divisible by the square of a prime ideal, [illegible] that the required factorization of p is either

$$p = A_1^2 A_2 A_3$$

where A_1, A_2, A_3 are prime ideals of first degree, or

$$p = A_1^2 A_2$$

where A_1 is of first degree and A_2 of second degree.

Hence the factors of F(x) are either

$$F(x) \equiv (P_1(x))^2 P_2(x) \cdot P_3(x) \quad (\text{mod. } p),$$

where $P_1(x)$, $P_2(x)$, $P_3(x)$ are prime functions of first degree, or

$$F(x) \equiv (P_1(x))^2 P_2(x)$$

where $P_1(x)$ is of first degree and $P_2(x)$ of second degree.

In order to find the prime ideal factors of p we have thus to resolve F(x) into its prime factors with respect to the modulus p. To do this we set

$$X^4 + ax^2 + bx + c \equiv (x - l)^2 (x^2 + mx + n) \quad (\text{mod. } p)$$
$$\equiv x^4 + (m - 2l)\, x^3 + (n + l^2 - 2ml)\, x^2 + (ml^2 - 2ln)\, x + nl^2. \quad (\text{mod. } p.)$$

Hence, for determining l, m, n we have the congruences

$$\left.\begin{aligned} m - 2l &\equiv 0 \\ n - 2ml + l^2 &\equiv a \\ ml^2 - 2ln &\equiv b \\ nl^2 &\equiv c \end{aligned}\right\} (\text{mod. } p).$$

Eliminating m and n, we get

$$\left.\begin{aligned} 4l^3 - 2la &\equiv b \\ 3l^4 - al^2 &\equiv c \end{aligned}\right\} (\text{mod. } p),$$

which give

$$2al^2 \equiv 3bl - 4c \quad (\text{mod. } p).$$

Having thus obtained the values of l, m, and n, we set

$$X^2 + mx + n \equiv (x + r)(x + s) \quad (\text{mod. } p)$$
$$\equiv X^2 + (r + s)\, x + rs. \quad (\text{mod. } p).$$

Hence,

$$\left.\begin{aligned} r + s &\equiv m \\ rs &\equiv n \end{aligned}\right\} (\text{mod. } p).$$

or

$$(r - s)^2 \equiv -4\,(a + 2l^2) \quad (\text{mod. } p).$$

(1) Hilbert, p. 201. (2) Hilbert, p. 196.

1. If $\left(\frac{-(a+2l^2)}{p}\right) = -1$, then $x^2 + mx + n$ is irreducible and we have

$$F(x) \equiv (x+1)^2 (x^2 + mx + n) \pmod{p}$$

and hence

$$(p) = (p, \Theta + 1)^2 (p, \Theta^2 + m\Theta + n).$$

2. If $\left(\frac{-(a+2l^2)}{p}\right) = +1$, then let $r - s = k$ be a solution of $(r-s)^2 \equiv -4(a+2l^2) \pmod{p}$ and we get r and s from the congruences

$$\left.\begin{array}{l} r + s \equiv m \\ r - s \equiv k \end{array}\right\} \pmod{p}.$$

We have then

$$F(x) \equiv (x+1)^2 (x+r)(x+s) \pmod{p}$$

and hence

$$(p) = (p, \Theta + 1)^2 (p, \Theta + r)(p, \Theta + s).$$

Case II. $p \pm \triangle$.

In this case we have the two relations

$$f_1(e_1 - 1) + f_2(e_2 - 1) + f_3(e_3 - 1) + f_4(e_4 - 1) = 0.$$
$$f_1 e_1 + f_2 e_2 + f_3 e_3 + f_4 e_4 = 4.$$

Now since $\triangle$ is the only prime which is divisible by the square of a prime ideal, the relations given above show that p can be factored in one of the following ways:

1. $(p) = A_1 \, . \, A_2 \, . \, A_3 \, . \, A_4$ where A_1, A_2, A_3, A_4 are all of 1st degree.
2. $(p) = A_1 \, . \, A_2 \, . \, A_3$ where A_1 is of 2d degree and A_2, A_3 of 1st degree.
3. $(p) = A_1 \, . \, A_2$ where A_1 and A_2 are both of 2d degree.
4. $(p) = A_1 \, . \, A_2$ where A_1 is of 1st degree and A_2 of 3d degree.
5. $(p) = A_1$ where A_1 is of 4th degree, in which case (p) is a prime ideal.

Hence F(x) can be factored in one of the following ways:

1. $F(x) \equiv P_1(x) \, . \, P_2(x) \, . \, P_3(x) \, . \, P_4(x) \pmod{p}$.
2. $F(x) \equiv P_1(x) \, . \, P_2(x) \, . \, P_3(x) \pmod{p}$.
3. $F(x) \equiv P_1(x) \, . \, P_2(x) \pmod{p}$.
4. $F(x) \equiv P_1(x) \, . \, P_2(x) \pmod{p}$.
5. $F(x) \equiv P_1(x) \pmod{p}$.

where $P_i(x)$ is a prime function of the same degree as the corresponding A_i.

In order to decompose $F(x)$ into its prime factors with respect to the modulus p we set

$$x^4 + ax^2 + bx + c \equiv (x - l)(x^3 + lx^2 + mx + n) \pmod{p}.$$
$$\equiv x^4 + (m - l^2)x^2 + (n - lm)x - ln \pmod{p}$$

hence,

$$\left.\begin{aligned} m - l^2 &\equiv a \\ n - lm &\equiv b \\ ln &\equiv -c \end{aligned}\right\} \pmod{p}.$$

from which we get

(1) $l^4 + al^2 + bl \equiv -c \pmod{p}$.

A) If (1) has one solution only, then the prime factors of $F(x)$ are $x - l$ and $(x^3 + lx^2 + mx + n)$ and the required factorization of p is

$$(p) = (p, \theta - l)(p, \theta^3 + l\theta^2 + m\theta + n).$$

B) If (1) has two solutions l and l'. Then $F(x)$ contains two factors of 1st degree and one of 2d degree and we have

$$F(x) \equiv (x - l)(x - l')(x^2 + sx + t) \pmod{p}.$$

where

$$\left.\begin{aligned} s &\equiv (l + l') \\ t &\equiv a + l^2 + l'^2 + ll' \end{aligned}\right\} \pmod{p}.$$

and hence,

$$(p) = (p, \theta - l)(p, \theta - l')(p, \theta^2 + s\theta + t).$$

C) If (1) has three solutions in which case it evidently must have four solutions l, l', l'', l''', then

$$F(x) \equiv (x - l)(x - l')(x - l'')(x - l''') \pmod{p}.$$

and hence,

$$(p) = (p, \theta - l)(p, \theta - l')(p, \theta - l'')(p, \theta - l''').$$

D) If (1) has no solution, $F(x)$ has no factors of 1st degree. Then we set

$$F(x) \equiv (x^2 + mx + n)(x^2 - mx + n') \pmod{p}.$$
$$\equiv x^4 + (n + n' - m^2)x^2 + m(n' - n)x + nn' \pmod{p}.$$

Hence,

$$(2) \quad \left.\begin{aligned} n + n' - m^2 &\equiv a \\ m(n' - n) &\equiv b \\ nn' &\equiv c \end{aligned}\right\} \pmod{p}.$$

If the system (2) is soluble we have

$$F(x) \equiv (x^2 + mx + n)(x^2 - mx + n') \pmod{p}.$$

and hence,

$$(p) = (p,\ \theta^2 + m\theta + n)\ (p,\ \theta^2 - m\theta + n').$$

If (2) is insoluble, $F(x)$ is irreducible and hence (p) is a prime ideal.

As an application we give a table of the prime ideal factors of certain rational primes in the number-field generated by a root θ of the equation

$$x^4 + x + 1 = 0.$$

Here $\triangle = 229$ and we get

$(229) = (229,\ \theta - 75)^2\ (229,\ \theta^2 - 79\theta - 71)$

$(2) = (2)$

$(3) = (3,\ \theta + 2)\ (3,\ \theta^3 + \theta^2 + \theta + 2)$

$(5) = (5,\ \theta + 2)\ (5,\ \theta^3 + 3\theta^2 + 4\theta + 3)$

$(7) = (7)$

$(11) = (11,\ \theta + 4)\ (11,\ \theta^3 - 4\theta^2 + 16\theta + 3)$

$(13) = (13)$

$(17) = (17,\ \theta - 3)\ (17,\ \theta^3 + 3\theta^2 - 8\theta - 6)$

$(19) = (19,\ \theta - 2)\ (19,\ \theta^3 + 2\theta^2 + 4\theta + 9)$

$(23) = (23,\ \theta + 4)\ (23,\ \theta + 5)\ (23,\ \theta^2 - 9\theta - 8).$

Dissociation-Potentials of Neutral Solutions of Lead Nitrate with Lead Peroxide Electrodes.

[**Abstract.**]

By Arthur Kendrick.

To determine if in such solutions and with lead peroxide electrodes electrolytic action takes place at voltages lower than that required for the separation of lead and lead peroxide with platinum electrodes, the method developed by Nernst[1] and Le Blanc[2] was made use of.

Two platinum wires coated with a thick, firm crust of lead peroxide were first used as electrodes. The current-potential curves obtained showed sharp bends at about 0.4 volt. To determine at which electrode the action at this voltage took place an electrode was made of a platinum wire projecting 1mm from a sealed glass tube. This point was coated with the lead peroxide before use each time. The other electrode con-

1. W. Nernst, Bericht. d. deutschen ch. Gesel. 30, p. 1547, 1897.
   L. Glaser, Zeit. für Electrochemie, 4, p. 355, 1898.
   E. Bose, Zeit. für Electrochemie, 5, p. 153, 1899.
2. LeBlanc, Zeit. für ph. Chemie, 12, p. 333, 1892.

sisted of a piece of platinum foil of several square c. m. area, coated with lead peroxide. Thus the two areas were vastly different; and nearly the whole of the polarization occurred at the point electrode, which was used successively as anode and as kathode.

When used as anode the current-potential curves showed the bend at about 0.4 volt. But used as kathode, the several curves were not in as good mutual agreement, and do not clearly indicate a particular voltage at which action at that electrode begins. The general indications are that the lead appears at a voltage considerably less than that required to separate lead on a platinum kathode, and that the peroxide is reduced. The irregularities that may mask the critical voltage seem to be due to local concentration changes around the electrode.

PbO_2 seemed to form at the anode at the voltage 0.4.

Some Observations with Rayleigh's Alternate Current Phasemeter.

By E. S. Johonnott, Jr.

This instrument in the field of alternate current measurements takes a place similar to that of the galvanometer in direct current measurements; with some advantages, and also with some disadvantages. For example, its indications may represent either current or electromotive force, and the angle of lag and true watts in a circuit may be obtained by a simple calculation. However, its indications, as in all other alternate current meters, vary as the square of the current; hence its range of sensibility is limited.

The principal feature of the instrument is the ease with which it gives the angle of lag of the current in a circuit behind the electromotive force impressed at its terminals. Also when once calibrated it gives all the quantities needed to determine the energy absorbed in a conductor.

Similar to the tangent galvanometer it consists of an iron magnet suspended in the field of the current whose value is required.

Fig. I is a horizontal sectional view of the form used by Lord Rayleigh. *M* represents the current coil, and is connected in series with the conductor on which the measurements are desired to be made. *S* represents the E.M.F. coil and is shunted across the terminals of the conductor.

Between the coils, *M* and *S*, with its center on their common axis, a piece of soft iron wire is suspended at an angle of 45° to the axis of the coils.

In the instrument with which the following observations were made, the coil *M* consisted of 72 turns of No. 22 copper wire wound in two sections having 48 and 24 turns respectively. *S* was similarly wound with No. 28 manganin wire and had a resistance of 668 ohms. Each was made adjustable along their common axis for a distance of 13 centimeters.

The needle was suspended with a fine phosphor-bronze torsion fiber. The deflections were measured with mirror and scale.

If an alternating current is sent through either of the coils, the needle becomes a magnet acted upon by a couple depending upon the instantaneous value of the current. The couple will be in the same direction whatever the direction of the current. In short, it will vary as the sine of twice the angle theta and as the mean of the square of the current values.

Since the couple varies as the sine of twice the angle theta, it will be a maximum for theta = 45°. Here also will be the position for the least sensitiveness to change in the zero.

In order to use the instrument as a phasemeter, readings of the deflection produced by the current in *M*, and the fall of potential in *S* are taken independently. Then, usually, two readings of the deflection produced by the currents in both coils simultaneously are taken—one in which both couples act in the same direction, the other when they act in opposite directions. The values of these two latter readings depend upon the angle of lag, and together with the reading for the currents, independently, give sufficient data for its computation.

The calculation may be made in two ways:

(1) Analytically.

(2) Graphically.

In the first method,

$$C_1^2 = A^2 + B^2 + 2AB \cos \phi$$

$$C_2^2 = A^2 + B^2 - 2AB \cos \phi \text{ when}$$

A^2 is the deflection with M acting independently.

B^2 is the deflection with S acting independently.

C_1^2 and C_2^2 is the deflection with M and S acting simultaneously.

ϕ may be found from either equation.

In the second method, two triangles are laid off with their sides proportional to the square roots of the readings. The angle of lag, φ, is given in either case as shown in Fig. II.

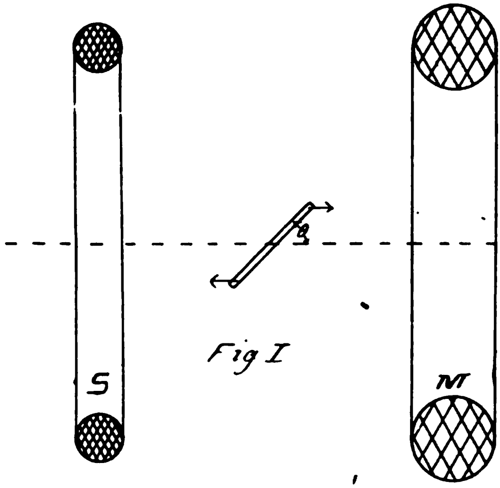


Fig I

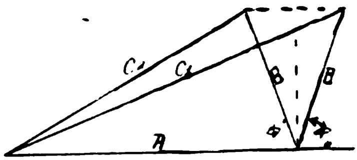


Fig II

$$C_1^2 = A^2 + B^2 + 2AB\cos\phi$$
$$C_2^2 = A^2 + B^2 - 2AB\cos\phi$$

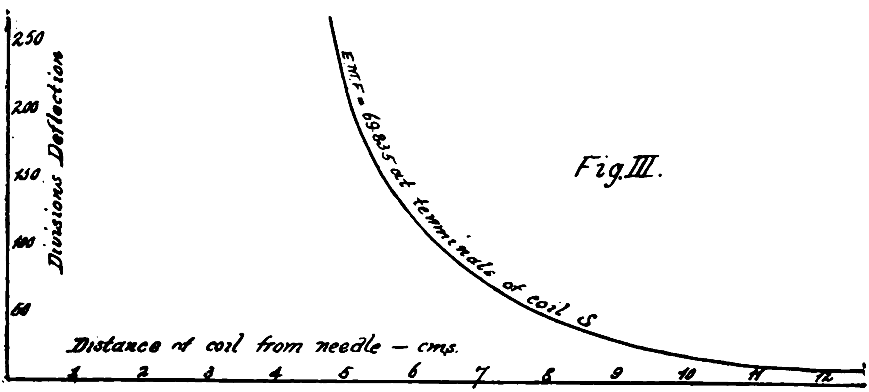


Fig. III.

Considerable range in sensibility for both coils is obtained by adjusting them at different distances from the needle. Some idea of this range may be obtained through inspection of the curve given in Fig. 3.

This was taken with the coil *S*, having a constant E.M.F. of 69.835 volts at its terminals. The abscissae represent the distances of the coil from the needle; the ordinates, the corresponding value of the deflections on the scale.

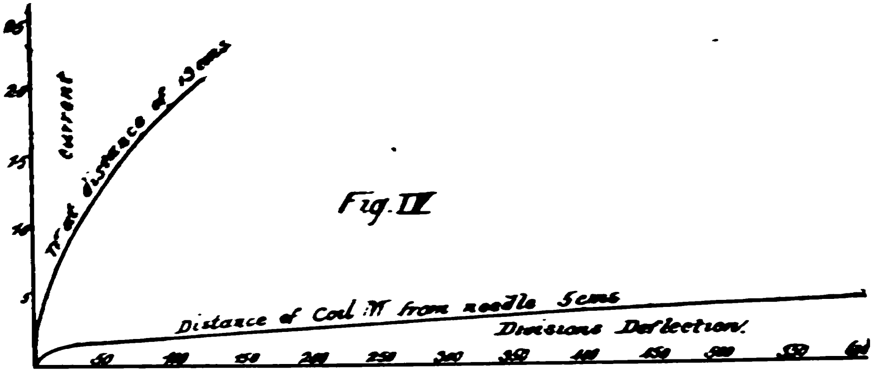
Both coils were calibrated at different distances from the needle with the Thomson balances. Fig. 4 represents curves taken with the coil, *M*, and shows no appreciable departure from the law of the squares.

In order to facilitate taking the readings, compensating coils, *M′* and *S′*, Fig. 5, were arranged in the circuit for *M* and *S* respectively, so that the conditions within the conductor on which the observations were being made remained the same when either *M* or *S* was cut out. This obviated removing either coil when the reading due to the current in the other was desired.

In Fig. 5 is shown a diagram of the connections used in making an observation for the angle of lag in a circuit which is here shown to be a coil, *X*, on a split anchor ring. *X* and *M* are connected in series in the secondary of a one-to-one transformer, in order to have no appreciable impedance in the circuit, other than *X*. The electrical conditions in this circuit were then controlled by the resistance and choking coil in the intermediate circuit. One commutator was arranged in the shunt circuit to reverse the current in *S*, another to substitute the compensating coil *S′* for *S*.

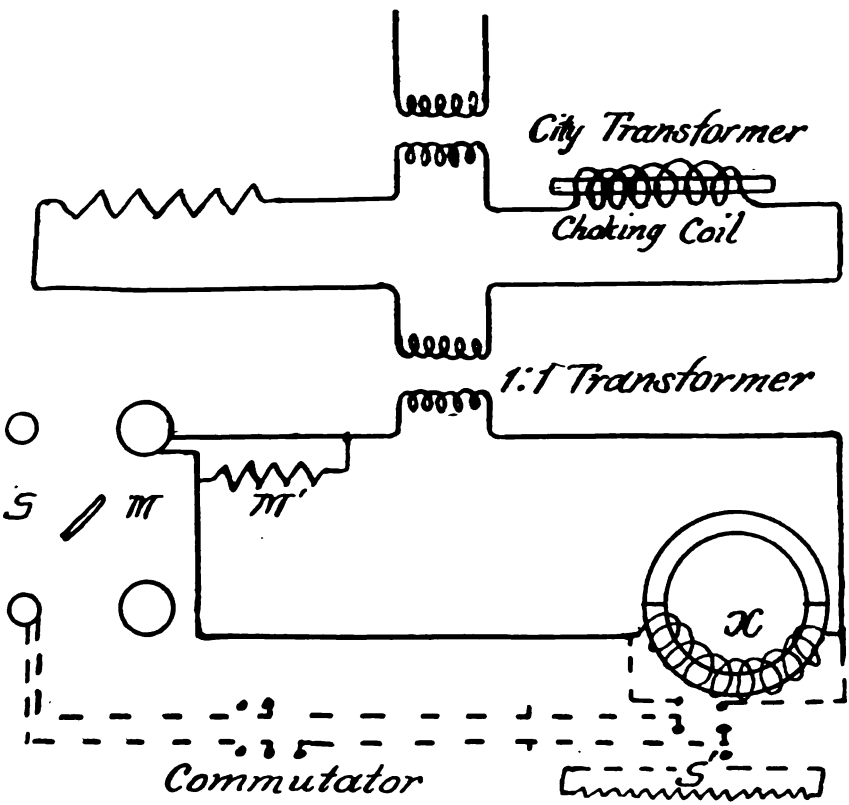
One of the greatest difficulties encountered in measurements of this character is due to unsteadiness in the source. Particularly is this true when all the readings can not be taken simultaneously. This may, however, in a measure, be overcome by arranging an auxiliary voltmeter similar to the E.M.F. coil, S, with its terminals connected across the terminals of the secondary of the city transformer. The phasemeter readings are then taken when the deflection due to their auxiliary coil is constant.

With respect to accuracy the phasemeter as a current meter is perfectly similar to the galvanometer.



Current
Distance of Coil M from needle 5 cms
Divisions Deflection
50
100
150
200
250
300
350
400
450
500
550
600

Fig. IV



City Transformer
Choking Coil
1:1 Transformer
S
M
M'
x
Commutator
S'

Fig. V

Some measurements on hysteresis and the effect of iron in the magnetic circuit have been undertaken. It would, however, be too premature to take up their description at this time.

The instrument which has been described was built, largely, by Mr. Edwin Place, formerly connected with the Institute. He made many observations similar to those above recorded.

I should like to take this opportunity to thank Dr. Gray for his many suggestions and for the removal of a number of stumbling blocks.

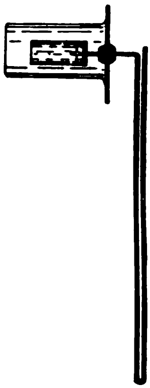
A Demonstration Apparatus.

By P. N. Evans.

The apparatus is a simple modification of that commonly used to compare, by diffusion, the density of another gas with air. It consists of a porous battery-cell placed horizontally and fitted by a stopper to a glass tube bent downwards at right angles a few inches from the stopper, and then upwards again to its original height. This U-shaped manometer is about two feet long and half filled with a dark-colored liquid; the limbs are close enough together to make a slight difference of level easily seen, against a white background fastened to the tube. To further increase the sensitiveness of the instrument a perforated glass plate or heavy card is secured between two corks on the horizontal part of the tube close to the cell, so that the cylinder or beaker of gas to be examined may be pressed lightly against this, and thus largely prevent loss of the gas before sufficient time has elapsed to show the maximum deviation in the manometer.

While the ordinary apparatus is recommended for demonstration only with gases differing considerably from air in density, this modification has given very satisfactory results with hydrogen sulphide, and even oxygen, with densities of 1.18 and 1.11 respectively, a difference in level of at least an inch being observed in the latter case. A slight effect, clearly visible to the manipulator, though not satisfactory for demonstration purposes, was obtained with nitrogen—density 0.972.

Still greater delicacy may be obtained by slanting the whole apparatus, giving the manometer a decided inclination.



Methylation of Halogen Amides with Diazomethane.*

By Jas. H. Ransom.

Since the classical work of Hofmann on the rearrangement of the halogen amides to derivatives of the isocyanates the mechanism of this reaction has been the subject of numerous investigations. Hoogewerff and van Dorp extended the work of Hofmann and pointed out the probability of a similarity in this reaction and that known as the "Beckmann rearrangement" of the oximes. After some more recent work on the brom-amides by Lengfeld and Stieglitz, the latter, with his pupils, studied the influence of the amide hydrogen atom on the rearrangement. He found that when this hydrogen was replaced by an alkyl radical no rearrangement took place in the sense of the Hofmann reaction, and suggested as the simplest and most reasonable explanation, that at some early stage of the reaction, under the influence of the alkali, the molecule

*This work was undertaken during the past summer, at the University of Chicago, in company with Dr. Julius Stieglitz.

lost hydrobromic acid, leaving monovalent nitrogen, which, by its reactivity, drew to itself the radical originally attached to carbon. As Stieglitz has pointed out, this explanation would account for the Beckmann rearrangement, and for that of the acid azides.

It seemed not without interest, therefore, to determine experimentally the position of the amide hydrogen in the halogen amide molecule. The two possible positions of this atom, R CO—N H/Cl and RC—(OH)=N Cl, correspond to the two classes of alkyl derivatives, chlor alkyl acid amides. R CO N R/Cl, and chlorimido acid esters, whose properties are now known. But the fact that the salts of such a molecule may have a different constitution from that of the free acid would make quite uncertain any conclusions drawn from the results obtained from the usual methods of introducing an alkyl radical.

Von Peckmann has shown that substances of an acid character react readily with diazomethane, forming a methyl derivative of the substance, the methyl entering where the hydrogen was attached. As the reaction is carried out with the free acid in absolute ethereal solution the probability of a rearrangement of the molecule during the process of methylation is reduced to a minimum. Ransom has shown, also, in two cases, that this method of methylation can be used to advantage in deciding delicate questions of constitution.

With these ideas in view, the following work was undertaken: Benzchloramide is best made by adding a solution of chloride of lime to a cold saturated solution of benzamide, which had previously been acidified with acetic acid, and extracting the oil which is formed with ether. On drying the ethereal solution with calcium chloride and evaporating the ether in vacuo without heating, a crystalline residue results which after recrystallizing from benzol was found to be 98.1 per cent. pure. The purity was determined by finding the percentage of active chlorine in the substance, by adding potassium iodide to a dilute alcoholic solution and titrating the free iodine with sodium thiosulphate. An ethereal solution of diazomethane was then prepared and some of the benzchloramide, suspended in a little ether, added to it until the yellow color of the diazomethane had nearly disappeared. Nitrogen was evolved in large quantities. When the action had ceased the ether was evaporated and there was left an oil with a peculiar but not unpleasant ethereal odor. The oil did not solidify even in a freezing mixture. Some of it was dissolved in ligroin and dry hydrogen chloride passed into the solution.

Chlorine was evolved and a white solid separated which was very soluble in water. The aqueous solution after standing some time gave off a distinct odor of benzoic ether ($C_6H_5COOCH_3$). Caustic soda separated from the solid an oil which had the characteristic odor of benzimido ether ($C_6H_5C{\overset{OCH_3}{\underset{=NH}{-}}}$). A quantity of the salt was heated in a bath to 118°. A gas (CH_3Cl) was evolved which burned with a green flame, and in the tube there remained a crystalline substance which proved to be benzamide. Some of the methylated chloramide was suspended in water and reduced with hydrogen sulphide. When the oil had become dissolved the solution was poured from the free sulphur and distilled with a concentrated solution of caustic soda, the distillate being collected in hydrochloric acid. This distillate was evaporated to dryness, and the residue extracted with absolute alcohol. Very little dissolved in the alcohol and no trace of methyl amine could be detected, nor of aniline by using either the delicate Jacquemine test or the isocyanide reaction. The properties of this substance therefore and its reactions correspond in every detail with what would be expected from the constitution,

$$C_6H_5C{\overset{-OCH_3}{\underset{=NCl}{}}}$$

Besides, benzchloramide is a fairly strong acid, as its alcoholic solution can be titrated against standard caustic alkalis, using either phenolphthalein or litmus as indicator. This acidity is not due to hydrolysis, thus forming free hydrochloric acid, since it gives with silver nitrate, even on standing, only a trace of silver chloride. A solution of the substance therefore contains hydrogen ions, a thing not to be expected on the supposition of an amide hydrogen. We may conclude therefore that benzchloramide contains an hydroxyl group.

Attempts were made to extend the investigation to other amides, viz., m—nitrobenzamide and anisic acid amide. The chloramide of the former however was found to be so unstable even at 0° that work on it was discontinued for the time. Anisic acid chloramide is also unstable, but at —5° enough of it was obtained to try the action of diazomethane upon it. The bleaching powder method was the one used to make the chloramide, but it always contained some of the dichloride, which was then converted into the monochloride by dissolving in caustic soda and reprecipitating it with acetic acid. As the least excess of acid decomposes it completely, the yields are very poor. A small amount of the substance, about 90 per cent. pure, was methylated as described above.

An oil was obtained which, when dry hydrogen chloride was passed into its solution, evolved chlorine, and deposited an oily solid salt. At 115°-120° it lost methyl chloride and there remained a crystalline substance which, however, was not the amide and contained chlorine. This was saponified with caustic soda, but the acid formed melted at 205°-210° and still contained chlorine. It is evident that at some stage the benzene ring became chlorinated. But the fact that methyl chloride was evolved on heating indicates that the methyl was united to oxygen.

A little preliminary work was done with the brom-amides, they being more easily prepared pure than the corresponding chlor derivatives. While the results were not conclusive, they indicated that either methylation occurred on the nitrogen atom or that a rearrangement of the amide to the amine had taken place. For a distinct isonitril odor was observed when the saponified product was boiled with chloroform and caustic potash. Besides when m-nitro benzbromamide was methylated a substance was obtained with quite different properties from those in the former cases. It contained a large amount of bromine, though almost inactive. A small amount of the substance gave a distinct test for formaldehyde (resorcin and sulphuric acid). This might indicate that a molecule of the brom amide had added itself to the methine (CH_2) group, thus:

$$R\,Co\,N^{H}_{Br} + CH_2 \longrightarrow R\,Co\;NH - CH_2\,Br.$$

This on saponification would give a derivative of formaldehyde and would contain inactive bromine.

The work will be extended in this and other directions as soon as opportunity offers.

Note on the Apparent Deterioration of Formalin.

By Thomas Large.

Attention of chemists and naturalists is called to the following facts: A stock of formalin, purchased from a prominent firm, for 40 per cent. formaldehyde, was kept at the Biological Station of Illinois for three years, where it was subjected to winter temperatures. When temperature was low a precipitate of white paraform (?) appeared, and was

redissolved with higher temperatures. In the past summer some difficulty was experienced with it in preserving larger fishes in warm weather. A sample of the formalin was submitted to Dr. Palmer, Professor of Chemistry in the University of Illinois, for examination. The following is his report on it: "We find that it contains 38½ per cent. of formic aldehyde. This is practically the quantity that is supposed to be contained in commercial formalin, i. e., 40 per cent. formic aldehyde. I find that nearly one-half of the formic aldehyde is polymerized, i. e., about 18½ per cent is in the form of the polymer tri-oxymethylene. I am not sufficiently familiar with the use of the formalin as a preservative to be able to state whether this polymerization will interfere with the use of the formalin as a preservative, but would suggest that possibly the formalin has proved unserviceable because nearly half of the constituent which is expected to do the work is in the form of the polymer, and probably unserviceable."

Notes on the Examination of Vegetable Powders.

By John S. Wright.

[Abstract.]

Brief accounts were given of the methods employed in preparing vegetable powders for microscopical studies, especially through the use of clearing and other microchemical reagents. References were made to the work previously done along this line and to the literature of the subject. Histological characters of vegetable powders were discussed, particular attention being paid to the value of the microscope as a means of identifying and detecting adulterations in granulated and powdered drugs and spices.

The Staining of Vegetable Powders.

By John S. Wright.

[Abstract.]

The use of differential stains to aid in the study of the histological elements of vegetable powders is in many instances important. If in

the study of a powder it may be stained differentially to correspond with the staining which can be employed upon various sections made of the original crude material, it becomes much easier to refer the minute granules and fragmentary elements to the tissues from which they originated.

There are two ways by which we may produce differentially stained powders for microscopical examination. The first and simplest is to make thick (½-¼mm) transverse sections of the tissues to be studied. These may then be stained in the usual manner, after which they are triturated in a mortar to a No. 60, 80 or 100 powder, as the case requires. Such powders are differentially stained in a satisfactory manner, but the fragments and cell masses often show truncated ends, due to sectioning, which are not found in powders produced wholly by grinding.

While the above process is an aid to the proper understanding of powders it is not of direct service in the great number of cases in which the microscopist is required to determine the identity and purity of powders. In such instances any staining method to be of service must enable the operator to differentially stain the powders directly. This may be accomplished by placing about ¼ or ½ gm. of the powder in a glass tube (50 to 60mm long and 10 to 15mm in diameter), one end of which has been closed by tying over it a piece of closely woven white silk cloth. Resting on this cloth bottom the powder may be treated with the various bleaching fluids, washed, double stained, dehydraded and cleared for mounting by allowing the tube to stand in watch glasses into which the stains and reagents have been poured. In this way a number of powders each in a separate tube may be treated at the same time. Owing to the great capillarity of fine powder it may often be necessary to promote the drainage and washings by blowing on the free end of the tube with the mouth; in this way it is possible to make rapid transfers from one reagent to another.

Cryptogamic Collections Made During the Year.

By M. B. Thomas.

During the past year some very interesting collections of cryptogams have been made in the local flora of Montgomery County.

These have been studied with special care and added to our already very complete list of the plants of the local flora. Very careful notes have been secured as to the distribution, variations and other important questions connected with the plants as collected.

During the early part of the year, in connection with the work in forestry, a collection was made of the fungi injurious to timber in our locality. The number of species was not as large as could reasonably be expected, and it seems that most of the devastation by fungi in our native forests is produced, in the main, by a very imited number of species.

Some additions have been made to our list of algae and a few to the collection of mosses. The latter list now includes 39 species.

Our most important contribution to the State flora is in the slime moulds.

During the past summer two students, Messrs. H. H. Whetzel and A. A. Taylor, devoted much time to this group. The result is an addition of 31 species to our list presented to you two years ago by Mr. Olive. This now gives us a total of 77 myxomycetes in Montgomery County. In addition to this we now have on hand some material not yet worked over, and doubtless several species in this are not included in our list. This is all the more interesting when we consider that our county is not particularly adapted to these forms of plant life and that the number reported is nearly two-fifths of the whole number found thus far in the United States.

The additions to the list are as follows. The classification used is the one presented by Lister in his Mycetozoa.

Order *Ceratomyxaceae.*

Ceratomyxa mucida Schroet.

Order *Physaraceae.*

Plysarum polymorphum var. *obrusseum* Rost.

Physarum calidris Lister.

Physarum newtoni Macbride.

Physarum compactum Lister.

Physarum globuliferum Pers. (Bull).

Physarum galbeum Wingate.

Chondrioderma spumarioides Rost.

Order *Didymiaceae.*

Didymium dubium Rost.

Didymium farinaceum Schrader.

Order *Stemonitaceae.*

Stemonitis tenerrima B. and C., Morg.

Stemonitis smithii Macbride.

Stemonitis webberi Rex.

Stemonitis confluens Cook and Ellis.

Comatrichia obtusata Preuss.

Comatrichia persoonii Rost.

Comatrichia laxa Rost.

Lamproderma arcyrionema Rost.

Order *Reticulariaceae.*

Enteridium rozeanum (Rost) Wingate.

Order *Heterodermaceae.*

Lindblandia tubulina Fries.

Order *Lycogalaceae.*

Lycogala exiguum Morg.

Lycogala flavo-fuscum Rost.

Order *Arcyriaceae.*

Arcyria incarnata Pers.

Arcyria oerstedtii Rost.

Arcyria digitata (Schw) Rost.

Arcyria ferruginea Sauter.

Arcyria cinerea (Bull) Pers.

Order *Trichiaceae.*

Hemitrichia intorta Lister.

Hemitrichia karstenii (Rost) Lister.

Trichia rubiformis Pers.

Experiments with Smut.

By M. B. Thomas.

On two previous occasions I have reported to the Academy some special progress made with experiments with formalin as a fungicidal agent.

The first report included the results of a series of experiments upon the effects of formalin in different strengths of solution, with varying periods of time, on the germinating power of a number of cereals.

The second report was the result of a practical field experiment based on the facts discovered by the earlier investigations. The conditions of this field experiment were not as trying or severe as might be desired, and although the results were highly gratifying, yet they did not seem as conclusive as we could wish. Accordingly, the past summer, another field experiment, on a somewhat larger scale, was tried in a part of the State where the smut of oats has been very destructive.

The trial was conducted on the farm of Chas. Baker, Noble County.

The last week in April three acres of oats were sown in three plats, the seed being treated respectively 40, 60 and 90 minutes in a solution of one part of commercial formalin to 200 parts of water. The seed was scattered broadcast without drying. Alongside of these areas was sown a field of untreated seeds. All of the seed used was from a previous crop of smutty oats that was very much infested.

No difference was noted in the time of germination of the several lots, but the treated seeds produced plants that were more uniform and better developed than those from the untreated ones.

At the time of cutting the difference between the two fields was very striking. Fully 15 per cent. of the heads of the untreated seeds were smutty, while not one stalk of the plants from the treated seeds showed any signs of smut. The whole experiment was conducted by the owner of the place from directions and material furnished by the department and the results were examined by one of our students. Of the three separate lots of treated seeds the ones soaked for 60 minutes seemed to be the best, and that time is recommended as safe and efficient for treatment. Comment on this experiment is unnecessary, and it is hoped that these facts may increase the use of this fungicide to the improvement of our production of oats.

The Flora of Lake Maxinkuckee.

By J. T. Scovell.

Lake Maxinkuckee is situated in Marshall County, Indiana. It occupies parts of sections 15, 16, 21, 22, 27, 28 and 34 of Township 32 north of Range 1 east of the second principal meridian. The lake is a little more than two and one-half miles long from north to south and about

one and one-half miles wide, having an area of nearly 1,900 acres. The surface of the lake is about 735 feet above tide. It is 150 feet above Lake Michigan, but 130 feet below the summit of the divide between Lake Michigan and the Wabash River. The lake is 15 feet above the Tippecanoe River five miles south, and about 75 feet above English Lake, 20 miles west. These elevations show that the lake is on a slope that descends gently toward the south and west. The lake is near the southwestern angle of the Saginaw moraine. The country about the lake is quite varied. There are hills and valleys, broad undulating plateaus, wet marshes and boggy swamps. The soils are sand, gravel, boulder, clay and swamp muck. There are more hills and clay and boulders on the east, more sand and gravel, more marshes and swamps on the west. On the east the surface rises somewhat abruptly to a general level of 75 or 80 feet above the lake, some hills reaching an elevation of about 140 feet. On the west there is a narrow divide 25 to 30 feet above the lake, then low land and swamp. The confused mingling of sand, gravel, clay and boulders, the irregular hills and the numerous kettle holes indicate that the surface features about the lake are of glacial origin. Just east of the center of the lake there are 15 or 20 acres of water that is from 85 to 90 feet deep. This deepest water is part of some 300 acres of deep water that forms the central portion of the lake. Fully one-half the area of the lake is shallow, the water being ten feet or less in depth.

Wells drilled from 75 to 150 feet through sand, gravel and clay, without reaching bed rock, indicate that the lake bed is wholly composed of morainic materials. In fact it seems to occupy a cluster of kettle holes, one long and deep, surrounded by several of lesser size and depth. The region drained into the lake is quite limited, being scarcely more than three times its area. "The Inlet" enters the lake from the southeast, Aubeenaubee Creek from the east, and Culver Inlet, with one branch from the north and one from the east, enters the northeastern part of the lake. These four streams, each rising within two miles of the lake, each largely fed by springs, are the principal inlets. Several very small streams, the outlets of springs, bogs, flowing wells and little swamps, contribute something to the waters of the lake. "The Outlet" is a sluggish stream which flows from the west side of the lake southerly into the Tippecanoe River. About 80 rods from the lake the outlet expands into a pond or lake, having an area of about 60 acres. This body of

water is shallow, at no place more than 12 feet deep. The greater part of its bed is muddy, and two-thirds of its outline is marshy. The ordinary variation in the level of the lake during the year is less than two feet. Such variation does not materially change the area of the lake or appreciably modify the various forms of life that inhabit its waters.

Perhaps one-eighth of the outline of the lake is low ground, marshy, swampy or boggy. But in general the muck or black mud is shallow, seldom more than two or three feet in depth, and it rests on a bed of hard sand or gravel. From the shore out to a depth of six or eight feet the lake bed is of hard sand or gravel, even along the low ground. At the mouths of the southeast and northeast inlets there are considerable areas of shallow mud over the sand, and at the mouths of the lesser inlets there is always a little soil. But for long distances along the steep banks of clay or gravel there is no fine soil, just sand or gravel. On the north, west and south this bed of sand and gravel supports an abundant growth of Chara, which is generally of small size and thickly crusted with calcic carbonate. This bed is also the home of immense numbers of bivalve mollusks. The chara and shells of dead mollusks yield considerable quantities of calcic carbonate. At first one would expect to find this material making deposits over the bed of this shallow water. But this calcic carbonate and other fine material is swept away and deposited in deeper water, where it helps to form the extensive marl beds of the lake. During the summer there are more winds from the east than from any other quarter, but during the year there are more westerly winds, and in general the westerly winds are stronger. There are also many northerly winds and many southerly winds, so that during the year there are numerous winds from each quarter. These winds pile up the water along the shores toward which they blow. This causes more or less of an undercurrent toward the deep water which carries with it all the fine material of the shallower water. As the westerly winds are more numerous and stronger these undercurrents are stronger on the east, carrying the fine material into deeper water, the marl beds commencing in eight to ten feet of water instead of in six to eight feet of water as on the other sides of the lake. The marl forms a rich soil which shades off into darker material under deeper water. During the winter ice forms to a thickness of from 15 to 25 inches. As the ice expands it crushes against the banks with great force. Where the shores are low the ice often pushes great quantities of sand and other materials up into

ridges, sometimes two or three feet high. These ridges or ice beaches are generally washed away by the high water common in spring, but sometimes they remain, making a distinct and somewhat peculiar plant region. Along the steep banks, the boulders that have fallen to the beach during the summer are crowded against the bank by the ice, making in some places quite extensive stone walls. With such a variety of soils as occur in and about Lake Maxinkuckee, a varied flora may be expected. In the waters of the lake there are great quantities of microscopic life, called *plankton*. Of the microscopic plants, protococcus, rivularia, oscillaria, diatoms, desmids and others are common everywhere in the open lake, but were most abundant among the higher vegetation along the shores. Occasionally rivularia would occur in such quantities as to be conspicuous to the naked eye. Spirogyra, vaucheria, oedogonium, hydrodiction, stigeoclonium, nostoc, cladophera, zygnema, chetophora, and others often occurred in masses in the shallow water. Chara and nitella were very abundant.

Nitella sp? A tall, slender plant, was abundant between 18 and 22 feet, ranging from 12 to 25 feet. In water from 20 to 25 feet deep we seldom found anything beside nitella.

Nitella sp? A small, delicate plant found in shallow water, common in the marshes and in the lake out to a depth of two feet.

Chara sp? A slender, rank-growing plant quite free from lime. Was abundant between 10 and 14 feet, ranging from eight to 24 feet. In some localities this chara was the only plant found between 10 and 14 feet.

Chara sp? A stout plant, seldom more than eight inches high, was thickly coated with lime. It was most abundant at a depth of from eight to 10 feet, often forming a thick mat of vegetation to the exclusion of other plants.

Chara sp? Much smaller than the above mentioned, quite abundant in shallow water, often the only vegetation. It was usually thickly coated with lime.

There are doubtless other species of chara and nitella about the lake, but the ones mentoned are the most abundant.

Potamogeton natans L. This plant was more common in the southwestern portion of the lake, growing in water from four to six feet deep.

P. amplifolius Tuckerm. This plant was abundant in water from five to eight feet deep, but ranged from two to 24 feet. On the Sugar Loaf bar, it was abundant and rank from nine to 24 feet.

P. lonchites Tuckerm. This pond-weed was common everywhere in shallow water. A cluster of rank potamogetons growing in eight to ten feet of water on Weed Patch bar I called lonchitis, but do not feel quite sure that I was correct.

P. heterophyllus Schreb. This plant was quite common out to a depth of four feet.

P. lucens L. This plant, sometimes called perch weed, was widely distributed, growing most commonly in water from six to eight feet deep.

P. praelongus Wulf. Not very common, growing in water from eight to 12 feet deep.

P. perfoliatus L. Not common, but quite abundant in a few localities in the south part of the lake. More common in water from eight to 12 feet deep.

P. zosteraefolius Schum. Quite common. More abundant between 10 and 16 feet, but ranging from two to 26 feet.

P. friesii Ruprecht. Widely distributed, more abundant between 12 and 16 feet, but ranging from eight to 25 feet.

P. pusillus L. More common in the southeastern portion of the lake in deep water, ranging from 10 to 24 feet.

P. pectinatus L. Forming thick masses, excluding other vegetation in water 10 to 16 feet deep, also in shallow water one to three feet deep. It often stands at the head of a steep slope.

P. robbinsii Oakes. Very common in the shallow waters of the Little Lake, but in the large lake more common in water from 10 to 18 feet deep, ranging from two feet to 24 feet.

Naias flexilis (Willd) Rost and Schmidt. Very abundant, ranging from one to 24 feet. Most common in the northeastern part of the lake.

Naias flexilis robusta Morong. This plant, while not common, was found in several localities

Sagittaria graminea Michx. In the shallow water of the Little Lake.

Philotria canadensis (Michx.) Britton. Very abundant in a few localities in shallow water, as near the head of the outlet. It is widely distributed in deep water, ranging from one to 22 feet.

Vallesneria spiralis L. Called Eel-grass. Said to be the wild celery of Chesapeake Bay. The plants bearing pistillate flowers grow in shallow water. I saw none deeper than two or three feet. The male plant was most abundant in water from eight to 18 feet deep. We found it as deep as 24 feet. The pistillate flower is carried to the surface of the water by a long thread-like scape. After fertilization the scape forms a spiral of several coils, drawing the ovary several inches under water, where the seeds ripen. The staminate flower has a short peduncle. When the pollen is mature, the flower separates from the plant and rises to the surface. The pollen, escaping from the anther, floats away to the pistillate flowers. The buds or stolons formed in the fall, on the male plant, are highly prized by mud hens and ducks as food. They will dive 10 or 15 feet for it. The shores are often thickly covered with the leaves they break off while getting these dainty bits of food.

Eleocharis interstincta (Vahl.) R. and S. In shallow water in both lakes, often forming large patches.

E. mutata (L.) R. and S. Abundant in shallow water near the mouth of the southeast inlet.

E. palustris (L.) R. and S. Found along the southern shore of Lake Maxinkuckee.

Scirpus americanus Pers. Common in the shallow water of both lakes.

S. lacustris L. Common in the western and southern portions of the lake out to a depth of seven or eight feet. Specimens from 10 feet to 13 feet long often occur.

Spirodela polyrhiza (L.) Schleid. Common in quiet waters about the lake shores.

Lemna trisulca L. Common in the outlet and in the southeastern inlet.

L. minor L. Often found with *Spirodela*.

Wolffia columbiana Karst. In the southeastern inlet and in the outlet.

Eriocaulon septangulare With. In Lake Maxinkuckee, but not common.

Brasenia purpurea (Michx.) Casp. Very abundant in the outlet, only occasionally found in the lake.

Nymphaea advena Soland. Common.

Castalia odorata (Dryand) Woods and Wood. Abundant in the outlet and in the Little Lake. Only occasionally found in the larger lake.

Ceratophyllum demersum L. Common everywhere to a depth of 24 feet.

Abundant in shallow water and quite plentiful between 14 and 20 feet.

Batrachium trichophyllum (Chaix.) Bossch. Abundant in the southeastern part of the Little Lake.

Roripa nasturtium (L.) Rusby. Abundant in the northeastern inlet and in other places.

Myriophyllum spicatum L. Abundant in the Little Lake and in the outlet. In water from two to eight feet deep.

Myriophyllum verticillatum L. Found in both lakes. Not deeper than 14 feet.

Utricularia purpurea Walt. In the outlet.

U. vulgaris L. In the outlet and Little Lake.

U. intermedia Hayne. In the outlet and Little Lake.

U. minor L. In the Little Lake and outlet.

U. gibba L. In the outlet.

U. biflora Lam. In the Little Lake.

Bidens beckii Torr. Found in both lakes. Not very abundant, but ranging from two to 20 feet in depth.

Peltandra virginica (L.) Kunth. Found in shallow water of both lakes, often in the mud along shore.

Pontederia cordata L. Common in shallow water of both lakes, often above water line along shore. Both of these plants, after fertilization, bend over, thrusting the ovary into the water or mud, where the seeds ripen.

On the marshes below the level of high water we found—

Dryopteris thelypteris (L.) A. Gray.

Equisetum fluviatile L.

Typha latifolia L.

Alisma plantago-aquatica L.

Sagittaria latifolia Willd.

Dulichium arundinaceum (L.) Britton.

Eleocharis ovata (Roth) R. and S.

Scirpus smithii A. Gray.

Acorus calamus L.

Xyris flexuosa Muhl.

Juncus effusus L.

Salix discolor Muhl.

Polygonum sagittatum L.

Decodon verticillatus (L.) Ell.

Mimulus ringens L.

Lobelia syphilitica L.

Cephalanthus occidentalis L.

Nyssa sylvatica Marsh.

Polygala cruciata L.

Spiraea tomentosa L. And more than sixty others, largely sedges and grasses.

In addition, along the beach, between low and high water, we found—

Panicum crus-galli L.

Muhlenbergia sylvatica Torr.

Cyperus diandrus Torr.

Polygonium pennsylvanicum L.

Impatiens biflora Walt.

Teucrium canadense L.

Lycopus virginiana L.

Mentha piperita L.

Mentha canadensis L.

Xanthium canadense Mill

Eclipta alba (L.) Hassk.

Bidens connata Muhl. And more than fifty others. In all making over two hundred plants in and about Lake Maxinkuckee growing below high water mark.

I desire to call attention specially to the following facts: First, that the bed of the lake is comparatively barren under water from two feet to six or eight feet deep; second, that there is an abundance of rank vegetation under water from eight feet to 20 feet deep; third, that we found no vegetation below a depth of 26 feet in Lake Maxinkuckee.

Generic Nomenclature of Cedar Apples.

By J. C. Arthur.

In a communication made to this society at a former meeting (December, 1898) the writer gave some account of recent studies in the nomenclature of plant rusts, especially as applied to species occurring in the State of Indiana.* At that

*Arthur, J. C.—Indiana plant rusts, listed in accordance with latest nomenclature. *Proc. Ind. Acad. Sci. for 1898:* 174-186.

time no extended study of the generic nomenclature of this group of fungi had been attempted, and the conclusions of Dr. Kuntze (*Rev. Gen. Pl. III*) were accepted as the most satisfactory at hand. Since then the ground has been gone over to some extent, and some questions worth public discussion have arisen. Among the most interesting of these is the correct appellation of the cedar apples.

Two species of cedar apples occur in Indiana; both forming swellings, or pseudo-apples, on the branchlets of red cedar in one stage of growth, and so-called rust spots on the leaves of various apples and thorns in the alternate stage. These were placed under the genus *Puccinia*, following the authority of Dr. Kuntze, one being *Puccinia globosa* (Farl.) Kuntze (*Gymnosporangium globosum* Farl. and *Rœstelia lacerata* Fr.), and the other being *Puccinia Juniperi-Virginianæ* (Schw.) Arth. (*Gymnosporangium macropus* Lk. and *Rœstelia pyrata* Thax.).

The development of the concept, now embodied in the genus containing the cedar apples and apple rusts, is an interesting one. Many of the earlier systematists placed the cedar apples among the algæ, and even after becoming fully recognized as fungi, it was long before their close relation to the other *Uredineæ* was firmly established. The apple rusts have been confounded with the cluster-cups of other genera, even quite recently, although it has now been nearly forty years since their connection with the cedar stage was first established. However, it is not with the development of the concept of the genus that this paper has to deal, but with the unfolding of its nomenclature.

Reviving the ancient usage of the generic name *Puccinia* in order to have it replace the familiar name *Gymnosporangium* was done in the interest of a stable nomenclature. The result shows, however, that a stable nomenclature is not to be obtained at a single dash, even when the principles are recognized and accepted that are to govern the procedure. Dr Kuntze (*Rev. Gen. Pl.*, Vol. 3, p. 507) gives Haller, 1742 (*Enum.*, Vol. 1, p. 17), the credit of founding the genus *Puccinia*, but Magnus (*Bot. Centr.*, Vol. 77, p. 4) has clearly shown that Haller's type material could not have belonged to the *Uredineæ*. The next subsequent author mentioned by Kuntze is Adanson, 1763. In accordance with the Rochester Code, Haller is excluded from consideration on account of antedating 1753, the initial date for priority, but Adanson might be accepted. This author presents an abbreviated diagnosis derived wholly from Micheli's classical work *Nova Plantarum* of 1729. It runs as follows: "*Puccinia Mich. t.* 92. *Tige élevée cilind, simple ou rameuse. Coriace. Toutela plante est formée de piramides ou filets en massues, couchés comme autant de rayons les uns sur les autres*" (*Familles des Plante*, Vol. 2, p. 8). Turning to Micheli, we find that he describes and figures two species under his genus, one evidently belonging to the *Uredineæ* and the other

not. According to Magnus this lack of singleness invalidates the name for replacing that of the De Candollean genus *Gymnosporangium*. It does not do so, however, in the writer's opinion, but it makes it necessary to decide which of the two species included is to be accepted as the type of the genus.

The idea of definite and unchangeable types is of comparatively recent growth. The type of a species is the individual plant to which the name is first given, and the type specimen is therefore an important adjunct in fixing the name and character of the species. In like manner the type of a genus should be the species mentioned under it, if there is but one given, but if more than one be given, and the author has neglected to designate the one to be accepted, it would seem to require for the sake of uniformity and stability that the first species named under the genus be assumed to be the type. This method in whole or in part has been ably advocated by Underwood, Cook, Jordan, Coville, Ward, Greene and others. Up to the present time it has been put into rigid practice to a limited extent only, the revision of American ferns by Prof. Underwood being the most conspicuous example, but it seems to the writer that the general acceptance of the rule will go far toward furnishing a stable basis for taxonomic nomenclature. To one who has watched the course of the present movement for a nomenclature that stands squarely upon priority, guided by uniform procedure rather than by individual judgment, the rule of types here set forth must seem a necessity that will inevitably be adopted sooner or later. It is for the sake of lending a hand in bringing about so desirable an end that the study of the cedar apple nomenclature is here presented.

If the rule of taking the first species mentioned under a genus as its type is applied, there can be no question that Adanson's genus *Puccinia* is to be accepted as a name antedating *Gymnosporangium*, and we may waive the discussion of the exact determination of the type, brought forward by Magnus. But this does not settle the matter.

In Linnaeus' *Species Plantarum* of 1753, which is accepted as the beginning of valid nomenclature, only two species occur belonging to the *Uredineæ;* one is *Lycoperdon epiphyllum*, now called *Puccinia epiphylla* (L.) Wettst., and the other is *Tremella juniperina*, known to be unquestionably *Gymnosporangium juniperinum* (L.) Wint. Linnaeus' genus *Tremella* contains seven species, the one just mentioned being the first, while the six which follow do not belong to the *Uredineæ*. The first species is characterized as follows (p. 1157):

> "Tremella sessilis membranacea auriformis fulva. *Fl. suec.* 1017.
> Byssus gelatinosa fugax, junipero innascens. *Fl. lapp.* 531.
> Habitat in Juniperetis primo vere."

Turning to Linnæus' flora of Sweden (*Fl. suec*, 1745, p. 368), where this species is the first named under the genus *Tremella*, and to his flora of Lapland *Fl. lapp.*, 1737, p. 370), it will be found that these lines are the descriptive names used in those works respectively, both works antedating the introduction of binomial names.

In Engler & Prantl's *Nat. Pflanzenfamilien* (Vol. 1, p. 92) Lindau has credited the genus *Tremella* to Dillenius, as has also Saccardo in his *Sylloge Fungorum* (Vol. 7, p. 780). Both these authors undoubtedly are following Fries in his classical work, *Systema Mycologicum*, of 1823 (Vol. 2, p. 210). The reference is clearly to Dillenius' *Historia Muscorum* of 1741, where we find seventeen species listed under *Tremella*, but strangely enough not one of these is a fungus. The first species, which we must consider the type, is characterized as "*Tremella marina vulgaris, Lactucæ similis*, Oyster Green or Laver." This is certainly a marine alga. In Linnæus' *Species Plantarum* of 1753 (p 1163) we will find this species given, with direct citation of Dillenius, under the name *Ulva Lactuca*, as the fifth of the nine species under the genus *Ulva*. It is certainly evident that Linnæus did not found his genus *Tremella* upon that of Dillenius, and that the twenty or more species of fungi now generally listed under *Tremella* as a Dillenian genus are not correctly referred.

It seems certain, if the method of types is accepted, that *Tremella* replaces *Gymnosporangium* as a genus of *Uredineæ*, and that the usage to which the name has generally been applied by modern systematists is erroneous. The same method of procedure shows eight generic synonyms of *Tremella*, which will be given without further comment, together with their type species and their respective hosts.

There are fifteen described species of cedar apples, of which eight occur exclusively in North America, two in both North America and Europe, three wholly in Europe, one in India and one in China and Japan. In order to show their status in the genus *Tremella*, and also for convenient review, they are here listed.

1753. TREMELLA *Linnæus.*

(*T. juniperina* on *Juniperus sp.*)

1763. *Puccinia* Adans. (*P. non ramosa* Mich. on *Juniperus sp.*).
1791. *Æcidium* Pers. (*Æ. cornutum* on *Sorbus aucuparia*).
1804. *Rœstelia* Reb. (*R. cancellata* on *Pyrus communis*).
1805. *Gymnosporangium* Hedw. f. (*G. conicum* on *Juniperus communis*).
1809. *Podisoma* Lk. (*G. fuscum* DC. on *Juniperus sp.*).

1826. *Centridium* Chev. (*C. Sorbi* on *Sorbus aucuparia*).

1826. *Ciglide* Chev. (*C. calyptratum* on *Pyrus communis*).

1877. *Hamaspora* Kœrn. (*H. Ellisii* on *Cupressus thyoides*).

1753. T. JUNIPERINA *L.* (Sp. plant. : 1625) Europe and North America.

I. On Sorbus, Aronia and Amelanchier. (*Rœst. cornuta* (Pers.) Fr.)

III. On Junip. communis and J. nana (*Gym. juniperinum* (L.) Wint.)

1785. T. SABINÆ *Dicks.* (Pl. Crypt. Brit. : 14.) Europe.

I. On Pyrus. (*Rœst. cancellata* (Jacq.) Reb.)

III. On Junip. Sabina and other sp. (*Gym. Sabinæ* (Dicks.) Wint.).

1788. T. CLAVARIIFORMIS *Jacq.* (Collect. 2 : 174.) Europe and North America.

I. On Cratægus (*Rœst. lacerata* (Sow.) Mer.)

III. On Junip. communis. (*Gym. clavariiforme* (Jacq.) DC.)

—— T. PENICILLATA (*Müll.*) *n. n.* (1780. *Lyc. penicillatum* Müll. Fl. Dan. t. 839.) Europe.

I. On Malus and Sorbus (*Rœst. penicillata* (Müll.) Fr.)

III. On Junip. communis. (*Gym. tremelloides* A. Br.)

—— T. MESPILI (*DC.*) *n. n.* (1815. *Æcid. Mespili* DC. Fl. France. 6 : 98.) Europe.

I. On Mespilus, Cydonia, Pyrus and Cratægus (*Rœst. Mespili* (DC.).

III. On Junip. Sabina (*Gym. confusum* Plowr.)

—— T. JUNIPERI-VIRGINIANÆ (*Schw.*) *n. n.* (1822. *Gym. Juniperi-Virginianæ* Schw. Schr. Nat. Ges. Leipz. 1 : 74.) North America.

I. On Malus. (*Rœst. pyrata* (Schw.) Thax.)

III. On Junip. Virginiana. (*Gym. macropus* Lk.)

—— T. BOTRYAPITES (*Schw.*) *n. n.* (1834. *Cœoma* (*Rœst.*) *Botryapites* Schw. Proc. Am. Phil. Soc. 4 : 294.) North America.

I. On Amelanchier. (*Rœst. Botryapites* Schw.)

III. On Chamæcyparis thyoides. (*Gym. biseptatum* Ellis.)

—— T. CLAVIPES (*C. and P.*) *n. n.* (1871. *Pod. Gym. clavipes* C. and P. Jour. Quek. Cl. 2 : 267.) North America.

I. On Amelanchier. (*Rœst aurantiaca* Pk.)

III. On Junip. Virginiana (*Gym. clavipes* C. and P.)

—— T. ELLISII (*Berk.*) *n. n.* (1874. *Pod. Ellisii* Berk. Grev. 3 : 56.) North America.

? I. On Aronia. (*Rœst. transformans* Ellis.)

III. On Chamæcyparis thyoides (*Gym. Ellisii* (Berk.) Farl.).

—— T. SPECIOSA (*Pk.*) *n. n.* (1879. *Gym. speciosum* Peck. Bot. Gaz. 3 : 217.) North America.

? I. On Amelanchier alnifolia. (*Rœst. Harknessiana* E. and E.)

III. On Junip. occidentalis. (*Gym. speciosum* Peck.)

—— T. GLOBOSA (*Farl.*) *n. n.* (1880. *Pod. fuscum globosum* Farl. Gym. of U. S. : 18.) North America.

I. On Malus, Cratægus, Sorbus and Cydonia. (*Rœst. lacerata* Am. Auct.)

III. On Junip. Virginiana. (*Gym. globosum* Farl.)

—— T. BERMUDIANA (*Farl.*) *n. n.* (1887. *Æcid. Bermudianum* Farl. Bot. Gaz. **12** : 206.) North America.

I. On Junip. Virginiana. (*Æcid. Bermudianum* Farl.)

III. On Junip. Virginiana. (*Gym. Bermudianum* Earle.)

—— T. CUNNINGHAMIANA (*Barcl.*) *n. n.* (1889. *Gym. Cunninghamianum* Barcl. Mem. Med. Off. India **5** : —.) India.

I. On Pyrus, Cotoneaster (*Æcid. Cunninghamianum* Barcl.)

III. On Cupressus. (*Gym. Cunninghamianum* Barcl.)

—— T. NIDUS-AVIS (*Thax.*) *n. n.* (1891. *Gym. Nidus-avis* Thax. Bull. Conn. Sta. No. 107 : 6.) North America.

I. On Amelanchier. (*Rœst. Nidus-avis* Thax.)

III. On Junip. Virginiana. (*Gym. Nidus-avis* Thax.)

—— T. KOREAENSIS (*Henn.*) *n. n.* (*Rœst. koreaensis* Henn. Monsunia 1 : —.)

I. On Pyrus, Malus and Cydonia. (*Rœst. koreaensis* Henn.)

III. On Junip. Chinensis. (*Gym. Japonica* Syd.)

ADDITIONS TO THE FLORA OF INDIANA.

BY STANLEY COULTER.

Since the publication of the "Catalogue of the Flowering Plants and of the Ferns and their Allies Indigenous to Indiana" numerous reports of additions have come to my hands. These reports have been examined with great care, in many cases the specimens themselves being submitted with the report. As a result quite a number of species are to be added to the flora of the State. It is gratifying to note, however, that the majority of these additions are to be found in the grasses and sedges, groups that have been largely neglected by collectors. Another considerable number includes extra-regional plants the occurrence of which within our bounds is to considered as exceptional, and which, while members

of the flora are only local or occasional. A third class includes escapes from cultivation, the inclusion or exclusion of which is largely a matter of individual judgment. The number of species added is much smaller than I had reason to expect in view of the fact that the original catalogue was based almost wholly upon accessible herbarium specimens, it being felt that in the absence of such verifying material the enumeration would lose much of its value. This rule led to the temporary exclusion of some of the forms which are now definitely reported and verified by accessible material.

SPECIES TO BE ADDED TO CATALOGUE.

Dryopteris spinulosa (Retz.) Kuntze. (Aspidium spinulosum Sw.)

Reported from Wells County by C. C. Deam, and from Wabash County by J. N. Jenkins. In fruit June 11.

Panicum sphærocarpon Ell. Round-fruited Panicum.

Porter County (E. J. Hill).

Panicum flexile (Gattinger) Scribn. Wiry Panicum.

Lake County (E. J. Hill).

Panicum verrucosum Muhl. Warty Panicum.

Porter County (E. J. Hill).

Bromus tectorum L. Downy Brome Grass.

Lake County (E. J. Hill). This seems to be the western limit of this form, which in favorable localities becomes a troublesome weed.

Agropyron repens glaucum (Desf.) Scribn. (A. glaucum R. and S.)

Lake County (E. J. Hill).

Cyperus Houghtoni Torr.

Lake and Porter Counties (E. J. Hill).

Eleocharis Robbinsii. Oakes.

Porter County (E. J. Hill).

Psilocarya nitens (Vahl) Wood. Short-beaked Bald-rush.

Porter County (E. J. Hill).

Psilocarya scirpoides Torr. Long-beaked Bald-rush.

Porter County (E. J. Hill). Britton and Brown give the range of this plant "In wet soil, Eastern Massachusetts and Rhode Island." The above citation extends the range of the plant far to the west. I have not seen the plant, but admit it because of the well known discriminative accuracy of Mr. Hill.

Fuirena squarrosa Michx.

Porter County (E. J. Hill).

Rhynchospora corniculata macrostachya (Torr.) Britton. (R. macrostachya Torr.)

Porter County (E. J. Hill).

Scleria reticularis Michx.

Porter County (E. J. Hill).

Scleria Torreyana Walp.

Porter County (E. J. Hill).

Scleria pauciflora Muhl.

Porter County (E. J. Hill).

Carex oligosperma Michx. Few-seeded Sedge.

Lake County (E. J. Hill). A species somewhat northern in its mass distribution, seeming to have its southern limit in the station just cited.

Carex limosa L. Mud Sedge.

Wells County (C. C. Deam). "Found on low borders of a small lake in Jackson Township. Scarce."

Carex glaucodea Tuckerm.

Lake County (E. J. Hill).

Carex decomposita Muhl. Large-panicled Sedge.

Wells County (C. C. Deam). "Growing in bunches of moss in bogs made dry by draining."

Xyris Caroliniana Walt. Carolina Yellow-eyed Grass.

Porter County (E. J. Hill). A species found in its mass distribution near the Atlantic coast.

Juncus bufonius L. Toad Rush.

Wabash County (J. N. Jenkins), Kosciusko County (C. C. Deam). "Low, sandy shore of Goose Lake, Kosciusko County."

Juncus articulatus L. Jointed Rush.

Lake County (E. J. Hill). A species decidedly northern in its distribution. Admitted upon the authority of Mr. Hill.

Juncus diffusissimus Buckley.

Crawford County (C. C. Deam). "Valleys about Wyandotte Cave." Britton and Brown give the range of this species, "Southeastern Kansas to Mississippi and Texas." The conditions surrounding Wyandotte Cave are such as to preclude the possibility of the form being introduced along highways or railways. The station given stands as the recorded eastern limit of the species. The determination was made by Mr. M. L. Fernald of the Gray Herbarium, Harvard University.

Stenanthium robustum S. Wats.

Wabash County (J. N. Jenkins). In some of the material examined the pedicels were elongated in fruit, but the form without question is to be referred as indicated above.

Quercus nigra L. Water Oak.

Crawford County, near Wyandotte Cave (C. C. Deam). By error this species was not included in the catalogue. It is fairly well distributed throughout the State, growing near streams and swamps, though sometimes found in upland regions.

Asarum reflexum Bicknell.

Lake County (E. J. Hill). This species was described in Bulletin Torrey Club, Vol. 24, p. 533, pl. 317, 1897. It is distinguished from *A. Canadense* by its smaller flowers, calyx tube white within, *lobes of the calyx limb early reflexed*, purplish-brown, 4″–5″ long, about as long as tube, *triangular*, with a straight obtuse tip 1″–2″ long. (Britton and Brown, Vol. 3, 513.

Mr. Hill reports that all the Asarums he has examined, growing about Chicago, prove to be of this species. None of the sheets in the Purdue herbarium, however, can be so referred. The Asarums should be carefully examined by collectors in order that the distribution of this form within our area may be determined.

Cycloloma atriplicifolium (Spreng) Coulter. (C. platyphyllum Moquin.)

Kosciusko County (C. C. Deam). "In sand pit near Eagle Lake."

Atriplex hastata L. (A. patulum hastatum Gray.)

Wells County (C. C. Deam). "Waste places and cultivated fields."

Allionia hirsuta Pursh. Hairy Umbrella-wort. (Oxybaphus hirsutus Sweet.)

Wabash County (J. N. Jenkins). This form has an assigned range to the west and northwest. Abundant material, however, places the reference beyond question.

Brassica campestris L.

Wells County (C. C. Deam). "Waste places."

Cardamine Pennsylvanica Muhl.

Wells County (C. C. Deam). "Five miles north of Bluffton, May 25, 1899."

Cleome serrulata Pursh. Pink Cleome. (C. integrifolia T. & G.)

Wells County (C. C. Deam). "On prairies south of Bluffton." The species has, perhaps. its eastern limit in Indiana, the assigned range being Illinois and westward.

Fragaria Americana (Porter) Britton. American Wood Strawberry.

Wells County (C. C. Deam). "In woods June 13, 1897."

Agrimonia hirsuta (Muhl) Bicknell.

Wells County (C. C. Deam).

Crataegus cordata (Mill) Ait. Washington Thorn.

Gibson County (J. Schneck, M. D.). An eastern, chiefly mountain form in Gibson County "on the higher hills."

Crataegus macracantha Lodd. Long-spined Thorn. (C. coccinea macracantha Dudley.)

"Along open bottoms in southwestern counties." (J. Schneck, M. D.)

"Banks of Wabash river, Wells County." (C. C. Deam.)

Prunus nigra Ait. Canada Plum, Horse Plum.

"In Woods," Wells County (C. C. Deam). The range of this species is well to the north of Indiana, but the abundance of material shows the above reference to be correct. In flower April 17, 1898.

Trifolium incarnatum L. Crimson, Carnation or Italian Clover.

Wells County (C. C. Deam). Somewhat widely escaped from cultivation within the last few years, but apparently not long persistent.

Oxalis cymosa Small. Tall, Yellow Wood-sorrel.

"Hill near Wyandotte cave, Crawford County, July 11, 1899." (C. C. Deam.)

Lechea tenuifolia Michx. Narrow-leaved Pin-weed.

Crawford County (C. C. Deam). "On hill near Wyandotte cave, July 11, 1899."

Vincetoxicum Shortii (A. Gray) Britton. (Gonolobus Shortii A. Gray.)

Crawford County (C. C. Deam). "On hill near Wyandotte cave, July 12, 1899."

Salvia lanceolata Willd. Lance-leaved Sage.

Gibson County (J. Schneck, M. D.). "On a sandy knoll in low river bottoms." An extreme western form having as its assigned range, "on plains, Nebraska and Colorado to Texas, Arizona and Mexico." The specimens submitted undoubtedly belong to this species, being easily separated from related forms by leaf characters and lobing of the connective. This eastern extension of range is extremely difficult of explanation, especially when the character of the station is taken into account.

Lonicera glaucescens Rydb.

Wells County (C. C. Deam). On bank of creek in Jackson Township, May 28, 1899.

Leontodon autumnale L. Fall Dandelion. Lion's Tooth.

Wells County (C. C. Deam). In yards at Bluffton, introduced in grass.

Helianthus petiolaris Nutt. Prairie Sunflower.

Lake County (E. J. Hill). A western prairie form occasionally found in dry, waste places eastward. Probably introduced into Indiana along east and west railway lines leading into Chicago.

Senecio Balsamitæ Muhl. (S. aureus Balsamitæ T. and G.)

Wabash County (J. N. Jenkins). The range of variation in *S. aureus*, so widely distributed throughout the State, is the only ground for questioning the above citation. The material submitted seems to bear out the description of the species *Balsamitæ*. It is therefore included in the list.

Centaurea Jacea L. Brown or Rayed Knapweed.

Lake County (E. J. Hill.) A form fugitive from Europe, usually found in waste places north, or in ballast about seaports.

Wolffiella Floridana (J. D. Smith). Thompson.

Marshall County, near Culvers (H. Walter Clarke). The abundant material furnished by Mr. Clarke leaves no room for questioning the accuracy of the reference. The range of the species by this citation is sharply extended northward, its assigned limits heretofore being "Georgia and Florida to Missouri, Arkansas and Texas.'"

Wolffia papulifera Thompson. Pointed Duckweed.

Gibson County (J. Schneck, M. D.). "Two miles east of Mt. Carmel, Ill., in Indiana. This is another decided extension of range, in this case eastward, the recorded range of the species being, "Kennett and Columbia, Mo." (Britton and Brown, Vol. 3, p. 510.)

SPECIES ESCAPED FROM CULTIVATION.

Pinus resinosa Ait. Canadian Pine. Red Pine.

Wabash County (J. N. Jenkins). A northern form which will probably not maintain itself in our area.

Populus balsamifera candicans (Ait.) A. Gray. Balm of Gilead.

Gibson County (J. Schneck, M. D.). Specimens of this form were in the Purdue herbarium at the time of collating the catalogue, but it was not included, being considered as an escape, and there being no record of its persistence.

Broussonetia papyrifera (L.) Vent. Paper Mulberry.

Gibson County (J. Schneck, M. D.). An evident escape from cultivation. The inclusion of the species should depend upon the persistence of the form in the wild state.

Malus Malus (L.) Britton. Apple.

"Along Wabash and White Rivers" (J. Schneck, M. D.). This form was excluded because regarded as an escape. The history of its persistence for many years in several different parts of the State has come into my hands since the publication of the catalogue. It should in all probability be included in the State flora.

Paulownia tomentosa (Thunb.) Baill. (P. imperialis S. and Z.)

Gibson County (J. Schneck, M. D.).

Tragopogon porrifolius L. Oyster Plant. Salsify.

Wells County (C. C. Deam).

Koelreuteria paniculata Laxm.

Gibson County (J. Schneck, M. D.).

These plants have undoubtedly escaped from cultivation in the locations cited. Whether or not they should be included in the State flora is a matter of personal judgment. Evidently fugitive plants which appear but for a single season in a single station can scarcely be regarded as entitled to place. That a plant escaped from cultivation should be listed as a member of the State flora in my judgment should require evidence, first, that it had maintained itself for at least three years; second, that in these years it was more than holding its own, in other words was making gains, however slight, in its new situation. For these reasons, in my opinion, the above plants, with perhaps the exception of the apple, should not be included in the flora. The list, however, is given for the benefit of those whose judgment would add them to the Catalogue list.

A few critical notes may perhaps find a proper discussion in this paper.

Quercus pagodæfolia Elliott.

Reported by Dr. Schneck as belonging to the flora of the southwestern counties. The question turns upon the point as to whether the form is to be regarded as a distinct species or merely as a variety. This form originally appeared as *Q. falcata* Michx., var. *pagodæfolia* Elliott, being separated from the type by "larger leaves, 11–13 nearly opposite and spreading lobes." Sargent includes it under *Q. falcata* Michx., and Britton and Brown under *Q. digitata* (Marsh) Sudw. In neither of these cases is it given even varietal rank. The form in our area is so well marked that it certainly seems entitled to varietal, if not, indeed, to specific rank. In my judgment, the form should be written *Q. digitata pagodæfolia* Ell., and given a place in the flora.

Quercus Phellos L. Willow Oak.

This form has been recorded as found in Gibson, Posey and Knox Counties. Concerning the occurrence of this species in this region, Dr. Ridgway says: "This species I give with some doubt, not being quite positive that it occurs. I have seen, however, along the road between Mount Carmel and Olney several trees which, at the time of inspection, I unhesitatingly decided to be *Q. Phellos*, but not having seen it since, while Dr. Schneck has not recorded it, I place the interrogation mark before it."[1] Since the publication of the Catalogue Dr. Schneck writes me that "a very narrow-leaved form of *Q. imbricaria* has probably been mistaken for *Q. Phellos*." If this be true, there exists no definite record of the occurrence of *Q. Phellos* in Indiana. Collectors in the southwestern counties should examine carefully as to the correctness of this view.

Celtis pumila (Muhl.) Pursh.

"Rocky banks of Blue River" (J. Schneck, M. D.). This shrub-like Hackberry, undoubtedly occurs in our area. It is included by Britton and Brown (Vol. 1, p. 526) under *C. occidentalis* L., which is described as a "shrub or a tree." Sargent also includes under *C. occidentalis*, of which he says: "A polymorphous species; the low shrub form of hillsides and sand dunes is the *C. pumila* of Pursh." The reasons for not maintaining *pumila* in at least varietal rank are not clearly apparent. The form, however, is in the Catalogue, by inclusion in *C. occidentalis.*

Some Mid-Summer Plants of South-Eastern Tennessee.

By Stanley Coulter.

The center from which the collections here reported were made was Mt. Nebo in the Chilhowee Mountains. It is about ten miles to the east of Maryville, which gives the nearest railway communication. From the summit of the mountain the eye reaches westward over a beautiful plain, to the Cumberland Mountains, while twenty miles to the east there arise the peaks of the Great Smoky Mountains. The region lying between the Chilhowee and Great Smoky Mountains is practically virgin, only relatively small areas having been taken for agricultural purposes. The

[1] Ridgway, Robert.—Notes on the Native Trees of the Lower Wabash and White River Valleys, in Illinois and Indiana. *Proc. U. S. Natl. Mus.*, 1882, p. 83.

time of the visit was the month of August, and while the object of the trip was not botanical, a few plants were collected and preserved as well as was possible under the conditions.

At the base of the Chilhowees runs Little River, its banks thickly clothed with timber, the most prominent form both as to size and number being the sycamore. More interesting was the fact that the mistletoe, which with us is found chiefly upon the elm, the honey locust and the oak, had there its favorite resting place upon the sycamore. Upon the western slopes of the Chilhowees, the chestnut was the characteristic forest tree, reaching very often a trunk diameter of from five to seven feet. In the coves and upon the western slopes of the Great Smokies, pines made up the forests, and we drove through miles of these forests which had as yet been free from the lumberman's axe. Near the summits of the Great Smokies the trees were for the most part stunted beeches, not more than fifteen to twenty feet high or with a trunk diameter exceeding eight inches. Among the pines there grew in abundance a bright yellow orchid which I was unable to collect, but took to be either *Habenaria cristata* or *lacera*. Upon the summit of Thunder Head in the wet places the Indian pipe grew in great masses, covering acres with its graceful, snow-white blossoms. In the lower levels and encroaching everywhere upon the cultivated areas the most attractive plant was the passion flower (*Passiflora incarnata*), known locally as maypop. It was one of the most annoying weeds of the region. The masses of rhododendrons and azaleas, though past the glory of their bloom, added another feature, strange to northern eyes. These plants practically covered the lower stretches of the mountain, and when in full bloom must have made a most brilliant landscape. No attempt was made to secure a complete collection of the plants of the region, only those being collected which promised to "preserve easily," or were of interest for some special reason.

Thanks are due to Mr. H. B. Dorner, a graduate student in botany at Purdue University, for a critical study of the collection.

Juniperus Virginiana L. Red Cedar.

Common over Chilhowee and Great Smoky Mountains.

Panicum capillare L. Witch Grass. Tumble weed.

Abundant and annoying in cultivated areas.

Commelina nudiflora L. Creeping Day-flower. (C. communis L.)

In moist places at base of mountains.

Stenanthium gramineum (Ker) Morong. (S. angustifolium Gray.)
Found chiefly well up the mountain sides.

Aletris farinosa L. Star grass. Colic-root.
In situations similar to the preceding.

Pogonia trianthophora (Sw.) B. S. P. Nodding Pogonia. (P. pendula Lindl.)
From base of mountain up to 2,500 feet.

Gyrostachys gracilis (Bigel.) Kuntze. Slender Ladies' Tresses. (Spiranthes gracilis Bigel.)
Usually well up the side of the mountain.

Tipularia unifolia (Muhl.) B. S. P. Crane-fly Orchis. (T. discolor Nutt.)
Not unfrequent on western slope of Mt. Nebo.

Carpinus Caroliniana Walt. Water Beech. Blue Beech. (C. Americana Michx.)
Along streams throughout mountains.

Polygonum Persicaria L. Lady's Thumb.
On Pine Top, Blount County, Tenn.

Silene stellata (L.) Ait. Starry Campion.
Abundant in woods throughout the mountains.

Anychia Canadensis (L.) B. S. P. Slender Forked Chickweed.

Clematis Virginiana L. Virgin's Bower.
Abundant along Little River, near Mt. Nebo.

Cassia nictitans L. Wild Sensitive Plant.
Extremely abundant. In places covering acres to the practical exclusion of other plants.

Cassia Tora L. Low Senna. (C. obtusifolia L.)
On banks of Little River, near Mt. Nebo.

Cassia Marylandica L. American Senna.
Found only about the Mountain House on Mt. Nebo, at an altitude of about 2,500 feet.

Stylosanthes biflora (L.) B. S. P. Pencil Flower. (S. elatior Sw.)

Meibomia nudiflora (L.) Kuntze. (Desmodium nudiflorum D. C.)

Lespedeza repens (L.) Bart. Creeping Bush-clover. (L. repens T. and G.)

Lespedeza frutescens (L.) Britton. (L. violacea sessiliflora Chapm.)

Lespedeza hirta (L.) Ell. Hairy Bush Clover. (L. hirta L.)

Lespedeza striata (Thunb) H. and A. Japan Clover.

Bradburya Virginiana (L.) Kuntze. Spurred Butterfly Pea. (Centrosema Virginiana Benth.)
Very abundant in the drier soils.

Rhynchosia erecta (Walt) D. C. (R. tomentosa erecta T. and G.)

Oxalis filipes Small. Slender Yellow Wood-sorrel.

On Mt. Nebo, on western slope, August, 1892.

Oxalis stricta L. Upright Yellow Wood-sorrel.

Abundant in moist soils along banks of Little River.

Polygala Curtissii A. Gray.

Polygala alba Nutt. White Milk-wort.

Very abundant in open places on Mt. Nebo.

Phyllanthus Carolinensis Walt.

Acalypha gracilens Gray. Three-seeded Mercury.

Abundant in thickets.

Euphorbia nutans Lag. Upright Spotted Spurge. (E. hypericifolia Gray.)

Euphorbia corollata L. Flowering Spurge.

Common throughout mountains.

Impatiens biflora Walt. Spotted Touch-me-not. (I. fulva Nutt.)

Near Little River, Blount County, Tenn.

Rhamnus Caroliniana Walt. Carolina Buckthorn.

Along banks of Little River, Blount County, Tenn.

Sida spinosa L.

Common throughout mountains and about cultivated fields.

Ascyrum hypericoides L. St. Andrew's Cross. (A. Crux-Andreæ L.)

Hypericum adpressum Bart. Creeping St. John's-wort.

Hypericum virgatum Lam. (H. angulosum Michx.)

Hypericum mutilum L. Dwarf St. John's-wort.

Sarothra gentianoides L. Orange-grass. Pine-weed. (Hypericum Sarothra Michx.)

Ludwigia alternifolia L. Rattle-box.

Angelica villosa (Walt) B. S. P. (Archangelica hirsuta T. and G.)

Cornus florida L. Flowering Dogwood.

On Pine-top mountain at 2,700 feet altitude.

Rhododendron maximum L. Great Laurel. Rose Bay.

Common in Great Smoky and Chilhowee mountains, along streams, forming dense thickets or "*slicks*" near the base.

Xolisma ligustrina (L.) Britton. (Andromeda ligustrina Muhl.)

Oxydendrum arboreum (L.) D. C. Sour-wood. Sorrel-tree.

Vaccinium virgatum Ait. Southern Black Huckleberry.

Mohrodendron Carolinum (L.) Britton. Silver-bell Tree. (Halesia tetraptera L.)

Ipomœa pandurata (L.) Meyer. Wild Potato Vine.

Abundant on Mt. Nebo.

Ipomœa pandurata hastata Chapm (?).

More abundant than the type especially in the lowlands bordering upon Little river.

Cuscuta arvensis Beyrich. Field Dodder.

On Pennyroyal, at foot of Mt. Nebo.

Hedeoma pulegioides (L.) Pers. Pennyroyal.

Solanum Carolinense L. Horse-nettle.

Banks of Little River, and in adjoining cultivated fields. Locally known as "Tread-softs."

Dasystoma laevigata Raf. (Gerardia quercifolia integrifolia, Benth.)

Ruellia ciliosa Pursh. (Dipteracanthus ciliosus Nees.)

Houstonia cœrulea L. Bluets. Innocence. (Oldenlandia cœrulea Gray.)

Houstonia purpurea L. (Oldenlandia purpurea Gray.)

Diodia teres Walt. Rough Button-weed.

Lobelia amœna glandulifera A. Gray. Southern Lobelia.

Abundant on Mt. Nebo.

Lobelia inflata L. Indian Tobacco.

Very common throughout the mountains.

Lacinaria squarrosa (L.) Hill. Blazing Star. Colic-root. (Liatris squarrosa Willd.)

On each side of Pine Top, Chilhowee mountains.

Graphalium obtusifolium L. Sweet Balsam. (*G. polycephalum* Michx.)

Near base of Mt. Nebo.

Silphium terebinthinaceum Jacq. Prairie Dock. (S. compositum Michx.)?

On Pine Top, Chilhowee Mountains in considerable abundance.

Achillea millefolium L. Yarrow.

Abundant throughout the mountains.

The nomenclature of the article is that of Britton and Brown's Illustrated Flora of the Northern States and Canada, the names in parenthesis being those used by Chapman in his Flora of the Southern United States, edition of 1872.

While Dr. Gattinger has done excellent work in the collation of the flora of Tennessee, there remains in the southeastern counties, especially in the deeper coves, large areas that as yet are practically botanically unknown. The remoteness of these regions from ordinary lines of travel, and the unprogressive character of the inhabitants, have joined to keep this area in a nearly virginal state. No collecting tour could be more profitable botanically than one through the coves and mountain ravines between the Great Smoky and Chilhowee Mountains.

A Study of the Constituents of Corn Smut.*

By William Stuart.

In connection with some studies upon corn smut, which were published in the twelfth annual report of the Indiana Experiment Station.[1] the question as to whether corn smut actually contained some principle injurious to farm animals was given some attention. This portion of the work, which was performed by the writer under the supervision of Dr. Arthur, was not completed in time for publication with the other studies mentioned. This work consisted in making extracts of the corn smut, and determining, by means of standard alkaloidal reagents, whether it contained an alkaloid or not. It also included a study of the physiological action of the extract upon horses, when administered to them either hypodermically or per orum. For the latter portion of the work the writer is greatly indebted to Dr. R. A. Craig, of the Veterinary Department, who administered the doses and observed its effects.

In the preparation of the extract valuable assistance was received from Mr. J. W. Sturmer, of the Purdue School of Pharmacy.

TESTS FOR ALKALOIDAL SALTS.

The methods employed in testing for alkaloidal salts were to make an alcoholic extract of the smut spores and such detritus as would pass through a fine sieve. A hundred grams of the smut spores were weighed out and, after thoroughly moistening them in an open dish with a 33⅓ per cent. solution of alcohol, they were again passed through a sieve to break up all lumps, then transferred to a percolator previously fitted up for the purpose. Sufficient alcohol, of the same strength as that previously mentioned, was added to cover the spores. Maceration of the spores was continued for twenty-four hours before any of the liquid was allowed to pass over into the receiving flask, the latter being so adjusted as to prevent it. At the end of this period the receiving flask was lowered so as to permit of about two drops passing over into the flask per minute. The percolation was continued until the percolate was colorless, sufficient

* Abstract of an article published in the Thirteenth Ann. Rep. of the Ind. Exp. Sta., pp. 26-32, Jan., 1901.

(1) Arthur and Stuart, Twelfth Ann. Report Ind. Exp. Sta., p. 84-135, Jan , 1900.

alcohol being added from time to time to keep the surface of the spores covered with the liquid. The first 50 cc. of the percolate was set aside and the balance collected and evaporated down to 50 cc. on a steam bath. This was added to the first amount saved making 100 cc. of the extract. Each cc. of the extract representing one gram of the spores.

In testing the extract for alkaloids a certain amount of it was taken and evaporated to dryness on a steam bath. The residue was treated with a five per cent. solution of sulphuric acid, and filtered. The filtrate was then subjected to tests with the following reagents:

1. Potassium mercuric iodide (Mayer's solution).
2. Phosphotungstic acid.
3. Iodine in potassium iodide solution.
4. Picric acid.

A small portion of the filtrate was poured out into each of four watch-glass crystals and then a drop or two of the reagents added. The reactions obtained by this method were as follows:

Reagent 1. A slight milky turbidity was produced.

Reagent 2. A decided milky turbidity was obtained.

Reagent 3. No visible reaction.

Reagent 4. No visible reaction.

A number of tests with the same and with fresh lots of extract prepared in the same manner gave similar results.

TESTS FOR TOTAL ALKALOIDS.

In testing for total alkaloids a modified "Prollius Fluid"[2] was used. Two methods were employed. The first was to treat two grams of the smut for four hours with 50 cc. of "Prollius Fluid" in a well stoppered conical flask. The contents of the flask were vigorously shaken at intervals during that period. After macerating four hours the supernatant solution was drawn off and filtered. The filtrate was evaporated to dryness on a steam bath and the residue treated with a five per cent. solution of sulphuric acid. The acid solution was filtered and the filtrate tested as mentioned for the alcoholic extract. The reactions obtained were in each instance similar to those given for alkaloidal salts.

The second method employed consisting in macerating ten grams of the smut spores in 100 cc. of "Prollius Fluid" for twenty-four hours. The

[2] Modified Prollius Fluid: Ether, 250 c. c.; Chloroform, 100 c. c.; Alcohol, 25 c. c.; 28% Ammonia, 10 c. c.

flask containing the spores being agitated at frequent intervals during that period. The supernatant liquid was drawn off and filtered, and 50 cc. of it transferred to a separatory funnel and subjected to the "shaking out" process as outlined in Sturmer and Vanderkleed's "Course in Quantitative Analysis: 61-64. 1898, under 'Process 1.—General for Total Alkaloid.'" The results obtained from this method by the reagents were quite similar, although more marked, to those of the preceding ones.

Reagent 1. A slight turbidity was obtained which, on standing for some time, deposited a dark brownish substance on the bottom of the glass.

Reagent 2. A marked cloudiness was obtained which, on standing for some time deposited a whitish crystalline precipitate on the bottom of the glass.

Reagent 3. No visible reaction or any deposit after standing.

Reagent 4. No visible reaction, but on standing a slight deposit was noticed on the glass.

TESTS FOR ALKALOIDS IN COMMERCIAL EXTRACTS OF ERGOT AND CORN SMUT.

The uniformity of the results obtained from the reagents employed, the first two giving positive and the last two negative reactions in each instance, led to an examination of the commercial extracts of both ergot and corn smut.

Ergot of rye test.—The commercial fluid extract of ergot was obtained from a leading wholesale druggist in the city, whose supply was obtained from the well-known firm of Park Davis & Co., of Detroit, Michigan. The fluid extract was evaporated to dryness over a steam bath, the residue treated with dilute sulphuric acid and filtered. Tests of the filtrate were made, and the reactions obtained were as follows:

Reagent 1. A yellowish brown, curdy-like precipitate was obtained.

Reagent 2. A cloudy white precipitate was obtained which on standing changed to a purplish brown, curdy-like substance.

Reagent 3. A reddish brown precipitate was obtained.

Reagent 4. No visible reaction obtained.

Corn smut ergot test.—The material used was obtained from the same local druggist, who in turn received his supply from the well-known firm of Merrill & Co., Cincinnati, Ohio. The fluid extract was treated in the

same way as in the preceding test and the reactions obtained were somewhat similar.

Reagent 1. A precipitate was formed, but it was not so marked as in the ergot of rye.

Reagent 2. Reaction much the same as that in rye ergot.

Reagent 3. Reaction not quite so marked as in the rye ergot.

Reagent 4. No reaction was obtained.

A brief summary of the work shows that a substance was obtained in all the extracts made which gave positive reactions with the first two reagents used and negative ones with the last two.

Commercial extracts of rye ergot and of corn smut gave similar reactions to those obtained from the corn smut extract prepared in the laboratory, in the case of reagents one and two, and in addition gave marked results with reagent three.

PHYSIOLOGICAL EFFECT OF AN ALCOHOLIC EXTRACT OF CORN SMUT UPON HORSES.

The study of the physiological effect of an alcoholic extract upon horses was carried on in conjunction with that of the alkaloidal tests in the laboratory, the alcoholic extract used being prepared by the writer in the same manner as that described in the preceding pages. The experimental work upon the horses was performed by Dr. R. A. Craig, of the Veterinary Department of Purdue University.

The appended notes upon the amounts and effects of the doses administered were taken by him and have been kindly placed at my disposal.

Horse No. 1.—A gelding, poor in flesh, but healthy, was given 15 cc. of the extract subcutaneously. The dose seemed to have no effect. The next day 30 cc. were given in the same way. In twenty-five minutes he stopped eating. The pulse and breathing were quickened and the peristaltic movements of the intestines were increased. Forty-five minutes after the drug was given faeces were passed. No further effects were noted.

Horse No. 2.—A gelding in good condition was given 25 cc. subcutaneously. In twenty minutes he became restless, stopped eating, and the pulse and breathing were quickened. A moist evacuation of faeces occurred in twenty-five minutes. An hour after giving the injection its effects had passed off. Two days afterwards 45 cc. were given. The horse

soon became restless, the intestinal murmurings were loud and an evacuation of faeces soon followed. When made to turn in the stall his movements were slow and unsteady. One hour after giving the injection his pulse was sixty and his respirations forty-three per minute. He refused to eat and remained dull till noon the following day. After an interval of a few days the horse was given 130 cc. per orum. In forty minutes he stopped eating, his pulse and breathing were quickened, but outside of this no other effects of the drug were noted.

A brief summary of the results show that an injection of 25 to 30 cc. of the drug caused restlessness and increased peristaltic movements of the intestines. This was followed shortly by evacuation of the contents of the rectum. At the same time the pulse and respiration were quickened. The effects of the dose passed off in an hour.

The injection of 45 cc. produced, in addition to the above symptoms, a dullness and an unsteady gait when made to move. The effects of the dose were much more lasting. The horse remained dull and refused to eat for twenty-four hours.

A 15 cc. subcutaneous injection and a 130 cc. per orum dose produced but little effect.

While the results of both the chemical and physiological tests of the corn smut are at variance with those obtained by some other investigators,[3] they are in accordance with results of a number of chemists,[4] and to some extent in their physiological action to that obtained by Dr. Mitchell,[5] whose experiments were performed upon the frog. The concordance of the results obtained from both the chemical and physiological tests would indicate the presence in minute quantity of some narcotic in corn smut. What this narcotic is, and why, when corn smut is consumed in large quantities by farm animals, it does not produce more harmful results, are questions which are yet to be determined.

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[3] Kedzie, Bull. Mich. Exp. Sta., No. 137 : 45, 1896.
Mayo, Bull. Kans. Exp. Sta., No. 58 : 69, 1896.

[4] Dulong, Journ. de Pharm. 14 : 556, 1828.
Cressler, Amer. Journ. Pharm. for 1861 : 306.
Parsons, Rep. Dept. Agric. for 1880 : 136–138, 1881.
Hahn, Amer. Journ. Pharm. 53 : 496, 1881.
Rademaker and Fischer, Med. Herald for 1887 : 775.

[5] Mitchell, Jas.—The Physiological Action of Ustilago maidis on the Nervous System, Inaug. Thesis, Univ. Pa., 1883. Therap. Gaz., Detroit, 10 : 223–227, 1886.

A Bacterial Disease of Tomatoes.*

[Abstract.]

By William Stuart.

During the winter of 1898-99, while engaged in an experimental study in the growing of tomatoes by the aid of chemical fertilizers, considerable annoyance was occasioned by the appearance of a disease which attacked the fruit and rendered it unmarketable.[1] Usually the fruit showed no sign

Fig. 1. Tomatoes affected with bacterial disease.

of injury until two-thirds grown, and sometimes not until fully developed. The first visible appearance of the disease in infected fruits was in a slight watery discoloration of the tissue beneath the epidermis. As the disease

[*Published in full in the Thirteenth Ann. Rep. of the Ind. Exp. Sta., pp. 33-36, Jan., 1901.]

[1]A disease similar in its character was reported by Beach, in Bulletin 125 of the New York State Agr. Exp. Sta., Geneva, pp. 305-306, July, 1897.

progressed, the affected portion assumed a darker color, followed by a gradual depression of the infected tissue, resembling in many cases that caused by the black rot Macrosporium solani (see Fig. I), but without any fruiting hyphae growing on the surface of the epidermis. It rarely wholly destroyed the fruit, but as a rule seemed to hasten its maturity. Generally the disease attacked the apical portion of the fruit; in a few instances, however, the central or basal portions would show the characteristic watery discoloration.

a b
Fig. 2. Original condition of the fruit prior to infection.

a b
Fig. 3. Changed condition of fruit "b" due to infection.

A microscopical examination of diseased portions of the fruit gave no evidence of the presence of any parasitic fungus. The presence of a motile bacillus seemed, however, to be fairly constant in all tissue examined.

Isolation of the germ.—In the isolation of the germ two different methods were employed. In one sections of the diseased tissue were removed from the fruit with a flamed knife and transferred to bouillon tubes, from which loop plate cultures were made in agar. In the other method direct

inoculation of the tubes were made from the inner portions of diseased tissue by means of a sterilized platinum wire.

The cultures obtained from both of these methods were apparently similar, both contained a minute motile bacillus, having the same appearance as that noted in the microscopical examination. The germ thus obtained was assumed at the time to be the same as that seen in the diseased fruit, but its after behavior did not in all respects bear this out.

Growth of the germ upon agar.—The growth of the germ upon slightly acid slant agar was quite characteristic; it produced a vigorous growth, with irregular outline all along the track of the needle. The color of the colonies upon agar was creamy white on the margins, becoming yellowish towards the center, and having a marked viscid surface.

Inoculation experiments.—On February 15 two tomatoes which had every appearance of being perfectly healthy were removed from plants in an adjoining room. One of these was inoculated with a pure culture of the germ, by puncturing the epidermis with a sterilized needle, and with a sterilized platinum wire transferring the germs from the tube to the interior of the fruit. The other fruit was infected by merely smearing the germs over the surface of the pistillate portion of the fruit. After inoculation both fruits were placed under a bell jar. At the end of the second day the first fruit showed signs of infection; a portion of the cells adjacent to the opening made for the introduction of the germ were fast turning a dark color. In a week the greater portion of the tomato was diseased and was giving off an offensive odor. By March 1, or fourteen days after the time of infection, it was completely decomposed, while the one on which infection material had been smeared showed no signs of disease.

On March 2 two more healthy tomatoes were removed from the vines, and after photographing them they were inoculated in the same way as those in the previous experiment. The progress of the disease in this experiment was not quite so rapid as in that of the first, some twenty days elapsing before the whole fruit was affected. Like the first the fruit into which the germs were introduced was totally destroyed, while the other remained perfectly sound. The fruits were again photographed on March 22. Fig. II represents them previous to inoculation, while in Fig. III the changed condition of the diseased fruit is shown.

In order to determine whether the same effects would be obtained by inoculating the fruit on the vine, a cluster of fruit containing four half

to two-thirds grown tomatoes was selected for experimentation. Two of the tomatoes were inoculated by introducing the germs into the tissues of the fruit with a sterilized needle. In order to note the effect of the injury from needle puncture the third fruit in the cluster was punctured with a sterilized needle, while the fourth was reserved for control. All inoculations were made on the north side of the fruit in order to avoid any action of the sun upon the wounds. Three days later the tissues surrounding the infected portions of the first two fruits had begun to grow darker. From this time on the progress of the disease was quite rapid No ill effects could be noted on the fruit punctured with the sterilized needle, both of the latter fruits remaining perfectly healthy.

In comparing the action of the disease produced in the artificially inoculated fruit with that of one naturally infected, it will be noted that with the exception of the first appearance of the disease their action was entirely different. In the natural infected fruit there was no offensive odor, the disease rarely affected the whole fruit, and never caused a sloughing of the cell tissues, as did the artificial infections. The wide difference in the action of the germ in the natural and artificially infected fruits may indicate that they were not the same, although looking so much alike, or it may be explained by supposing that in the naturally infected fruits the epidermis, not being broken, excludes all putrefactive bacteria. The putrefactive bacteria having access through the wound caused by artificial inoculation, feed upon the tissues destroyed by the inoculated germ, and thus the two acting in conjunction make the destruction of the fruit much more rapid and complete. The uniformity of the results obtained seems to favor the latter assumption.

SUMMARY.

A decay of green fruits on tomato plants grown in the greenhouse seemed from microscopical examination to be of bacterial origin.

The fruit showed patches that looked watery, became depressed, and after a time turned blackish. Usually the disease started at the apical portion of the fruit. No evidences of a fungus were present. Attempts to separate a specific germ were apparently successful.

Introducing the supposed germ into the fruit by puncturing the epidermis in every instance produced a disease.

The disease caused by the germ from the cultures did not coincide very closely with that from natural infection, and there is still doubt if the two be the same.

No preventive measures can be suggested with the limited knowledge of the disease yet available.

Device for Supporting a Pasteur Flask.

By Katherine E. Golden.

Notes on the Microscopic Structure of Woods.

By Katherine E. Golden.

Movement of Protoplasm in the Hyphæ of a Mould.

By Katherine E. Golden.

Description of Certain Bacteria Obtained from Nodules of Various Leguminous Plants.

By Severance Burrage.

(A preliminary study on the constancy of the distribution of bacterial species in definite species of leguminous plants.)

It has been quite thoroughly proven that several different species of bacteria may be found in the nodules of various leguminous plants. The following questions, however, have not, it seems to me, been definitely settled with regard to them:

Does the same species of bacteria always occur in the same species of legume?

Does the same species of bacteria always occur throughout all the nodules on the same plant of any species of legume?

Does the same species of bacteria always occur in the nodules of all the plants in a field planted with one species of legume?

Does the same species of bacteria occur constantly in the same species of legume year after year?

The following descriptions are merely the beginning of an attempt to investigate and answer these questons.

For much of the culture work, I am indebted to Mr. T. R. Perry, one of the students in Purdue University last year.

SPECIES 1.

Separated twenty times from the nodules of Trifolium pratense.

MORPHOLOGY.

Bacilli with rounded ends, occurring sometimes singly, but generally in pairs. These bacilli measured from .75 to 1 mu in width, and 2 mu in length. Examination of Zoogloea masses on agar shows a distinct capsule formation sometimes measuring 3 mu in width and 4 mu in length.

BIOLOGICAL CHARACTERS.

An aerobic, liquefying, motile, chromogenic bacillus, growing well at room temperature, but slightly better at 37½ C°.

On gelatin plates the colonies are large and white, liquefying the gelatin in a very short time.

A funnel shaped liquefaction occurs in gelatin stab cultures in about 15 days, and a distinct greenish fluorescence is given to the liquid portion, while a white precipitate sinks to the bottom of the "funnel." After all the gelatin is liquefied, a distinct green mycoderm is formed on the surface.

On the agar streak there is a thin, spreading light-green growth which imparts a distinct fluorescence to the agar. On older cultures, this growth thickens and forms a luxuriant zoogloea mass all over the agar. It is from such conditions that the capsule stage may be obtained. Upon potato a slimy, yellowish, dirty-brown growth takes place along the line of inoculation, which growth becomes darker with age.

Milk is quickly coagulated, and the whey takes on a greenish fluorescence. This milk, however, remains neutral.

In solutions containing nitrates, all nitrates are changed to nitrites in from five to seven days.

Glucose solutions are not fermented.

SPECIES 2.

Separated several times from the nodules of Vicia sativa.

MORPHOLOGY.

In crushed nodules the "bacteroid" appearance is quite common, while on the various artificial culture media these are rarely seen. Upon these media, they appear as bacilli with rounded ends, often united in pairs. They measure .8 mu in width and 1.5 mu in length.

BIOLOGICAL CHARACTERS.

This form is a faculative anaerobe, motile, non-liquefying, non-chromogenic. Grows well at the room temperature, and better at the body temperature. In gelatin stab cultures a line of very small colonies is formed along the line of puncture.

On agar plates the colonies appear in thirty-six hours, the surface colonies having a whitish appearance, while the deeper ones have a yellowish tinge.

The agar streak gives rise to a slimy, viscous, whitish growth, having no tendency to spread over the agar.

On potato, a rather restricted whitish growth takes place very slowly, and this growth is very slimy.

In solutions containing nitrates, after twenty days, a considerable portion have been reduced to nitrites, but not all, as there was positive test for nitrates as well as for nitrites.

Glucose solutions are not fermented.

Milk is not coagulated, yet is rendered strongly acid.

SPECIES 3.

Separated in several instances from nodules of Phaseolus nasus.

MORPHOLOGY.

Bacilli with rounded ends, usually united in pairs.

Measurement, 1.5 mu in width, 3 mu in length.

BIOLOGICAL CHARACTERS.

An aerobic, liquefying, motile nonchromogenic bacillus, which grows very slowly at the room temperature, but quickly at the body temperature. In gelatin stab cultures the liquefaction occurs in a straight line across the tube. The whole mass of gelatin becoming liquefied in 15 days.

On gelatin plates the colonies reach one-sixteenth of an inch in diameter, circular in outline.

On agar plates, the colonies are also about one-sixteenth of an inch in diameter, but are somewhat irregular in outline, and very finely granular.

On the agar streak, there is a luxuriant dirty-white, slimy growth, giving a very slight fluorescence.

On potato, there is at first a flesh-colored growth, later becoming a dirty white, and on the very old cultures, a brown.

Glucose solutions are not fermented.

Nitrate solutions give a fair test for nitrites after 24 days.

Milk is in no respect changed by this species.

SPECIES 4.

Found in several nodules on Trifolium hybridum.

MORPHOLOGY.

Bacilli occurring usually in pairs, rarely singly.

In the nodules. these bacilli measure 1.5 mu in width, and 4 mu in length. When taken from culture media they measure 1.75 mu in width and 5 mu in length.

BIOLOGICAL CHARACTERS.

This form is a facultative anaerobe, non-liquefying, non-chromogenic bacillus, quite actively motile. Grows better at the body temperature than at the room temperature.

In gelatine stab cultures there is a scattered growth of individual colonies along the line of inoculation, without liquefaction of the gelatin. An irregular button-like growth takes place on the surface of the gelatin. In bouillon rendered slightly acid, no growth whatever took place, while in neutral bouillon an abundant growth occurred.

On agar streak a non-spreading flesh-colored growth appears, and on potato a light lead colored growth follows the line of inoculation which becomes slimy after four days.

Glucose solutions are not fermented.

Nitrate solutions are wholly reduced to nitrites.

Milk is unchanged.

SPECIES 5.

Found in nodules on several plants of Trifolium reflexum.

MORPHOLOGY.

Bacilli usually arranged in pairs, rarely singly. They measure .5 mu in width, and 1.5 mu. in length.

BIOLOGICAL CHARACTERS.

This species is a non-liquefying, non-chromogenic, motile, facultative anaerobic bacillus, which grows very well at the room temperature, but not so well at the body temperature.

On gelatin stab cultures a few scattered colonies appear along the line of inoculation, and a button-like growth on the surface. The gelatin is not liquefied in two weeks.

On agar streak, a whitish growth follows the line of inoculation.

On potato the growth is a yellowish, lead-colored one, following the line of inoculation.

Glucose solutions are not fermented.

Nitrate solutions are completely reduced to nitrites in three days.

Milk is coagulated, but remains neutral.

Other species are now being worked upon, which have been separated from many other leguminous plants, including crimson clover, locust, small white clover, whippoorwill cow pea, black cow pea; and alfalfa.

A Few Mycological Notes for July and August, 1900, Wells and Whitley Counties.

By E. B. Williamson.

An interest in the doings which go on in fields and woods is natural to everyone, bearing, as all of us do, in our own brains, cells which still retain the impress given them as they developed and multiplied to gradually make man, by the cunning of his intellect, master of his environment. Interest is attracted most easily to those everyday, more conspicuous and beautiful objects, and those which have never been dangerous to man during the period of his later evolution. So at the present time we have popular illustrated works on birds, butterflies and

flowering plants, and when the Garden shall have faded into a more correct perspective, we may expect some such popular treatises on the humble though usually beautiful, creatures which go with heads in the dust. But I leave it to the student of psychogony to discover why the fastidious human so often turns with loathing from a mushroom. It would seem that these plants, by their graceful adaptive forms and varied colors, could easily conquer the feelings which seem to frequently exist only because of the falsely suggestive name of "toadstools" commonly given to all species of the Agaricaceae. However, an interest in these larger fungi is felt by many, and one purpose of this brief note is to call attention to two recently published works which make possible at least a general knowledge of the forms to be found in the United States.

The first of these books is "Moulds, Mildews and Mushrooms," by Dr. Underwood, published by Henry Holt & Company. Keys enable the student to trace specimens to their genera, and notes on distribution, habitat, etc., conspicuous species, and a full bibliography are given. The second book is "A Thousand Fungi," by Charles McIlvaine, published by the Bowen-Merrill Company. Many fine plates from photographs and water color studies illustrate a large number of species, especially the commoner and more conspicuous forms. This work is decidedly less scientific that the first, and the many notes are usually intended especially for the mycophagist.

To the best of my knowledge those who gather fungi for food purposes in Wells County, and doubtless also in other portions of the State, confine themselves exclusively to the morel. This species is not rare in the spring. It belongs to another group than the one to which other mushrooms, as they are known, belong. Near Bluffton a species of *Geoglossum*, a genus belonging to the same order as *Morchella*, was not rare in low woods in August. It was not found in sufficient quantities to cook, but eaten raw had a nutty flavor, woody texture.

In low woods on and about rotting logs in Wells and Whitley counties during August *Clavarias* were common. *C. cristata* seemed to be the common species. Underwood says none of them are deleterious, and McIlvane recommends some of them especially for soups. In past years species of *Hydnum* have been observed commonly in the two counties mentioned above, but this year, possibly because of the little time spent in the woods compared with some former years, none were seen.

On August 17 an oak stump growing in a thick woods near Bluffton was found literally covered with *Polyporus sulfureus.* No other mass of color could have clothed the stump to render it more conspicuous in the dark woods. The fungus was young and tender, and a number of persons ate of it sliced and stewed. The flavor possibly suggested veal. I have seen this species growing more in the open on logs where it was almost completely pulverized by insect larvae.

Of the Boletaceae three genera were observed in Wells County—*Fistulina, Boletus* and *Boletinus.* None of these were tested for their edible qualities. *Fistulina hepatica* was found only once, on August 25. *Boletinus porosus* grew in shaded woods among old leaves. The short stipe and mottle yellow-ochre and burnt umber pileus of this species render even large specimens six or seven inches in diameter inconspicuous. One species of *Boletus* was common in both Whitley and Wells counties, but was not specifically identified. Height, two inches; diameter of pileus, one and one-half inches; pileus above, chocolate brown, reddish or reddish yellow; flesh, white or very pale yellow, when broken becoming bluish, then very dark yellow; tubes yellow; stipe solid, reddish yellow, not annulated.

Pleurotus ostreatus to the mycophagist is one of the most valuable fungi in northern Indiana. About Bluffton it was found especially on the northern exposures of elm logs which still held their bark, though it has a wide range of habitat. To some its flavor is as good as any mushroom, and the quantities that can often be gathered after a rain from one log recommend it. It often becomes soggy during a rainy spell, but if it is not too much infested with larvae this does not interfere with its edibility. Fried in butter this species is as good as cooked any other way. It is attacked by more enemies than any other woods species of fungus I have noticed. At least two or three species of mollusca, two diptera, possibly a dozen coleoptera and two hymenopetera infest it. A friend reports grasshoppers feeding on it. Centipedes are often found among the gills, being there doubtless in search of insect prey.

Amanita phalloides was found once in a cleared spot in a thin woods near Shriner Lake, Whitley County. This was the only one of the few deadly mushrooms seen during the season. A species which is perhaps dangerous is *Lepiota morgani.* It reaches the maximum of size for an Agaricaceae. One specimen collected at Bluffton was ten inches high, and the pileus was eleven inches in diameter. Another specimen broken off at the ground weighed eleven ounces. I saw the species growing at only two

stations and at one of these it formed an incomplete giant fairy ring as has been described. At Bluffton eight persons ate freely of this species, and none suffered any inconvenience. It is generally accepted that genuine cases of mushroom poisoning have never resulted from eating decomposing nonpoisonous species. But is it possible that the ripening of the spores might develop some minor poison? The specimens of *L. morgani* eaten at Bluffton were in every case young and the gills were not colored by the spores. Several small species of *Lepiota* were common in the woods during August, but none of these were specifically determined. One of them had the pileus usually under an inch in diameter, white, the umbone dark wood brown. As it aged the margin of the disc became a delicate and beautiful blue.

Another dangerous species is *Clitocybe illudens*. This was found twice near Shriner Lake, growing on stumps, once in an open field, the second time in the woods. None were cooked. Dr. Underwood says it is unwholesome; Mr. McIlvaine says it is poisonous to some, and its odor is certainly not attractive. It possesses fully the phosphorescent property attributed to it by authors. *Clitocybe monadelpha* was found twice near Bluffton, each cluster growing on the ground in low, thick woods. Another species was very common about logs in woods. It was gray or light brown in color, thin, woody, and wine-glass shaped. The odor if long continued was sickening. On two occasions, when I had a quantity of it in the room where I was working, it all but nauseated me, though I am not easily offended through my olfactory organ.

Collybia radicata was common in Wells County, and it and two larger species of the same genus, all, growing in woodland, were frequently eaten. They have nothing in particular to recommend them. *Russula emetica* was taken in Wells County and *Russula roseipes* in Whitley County. The latter species was eaten raw. It had a nutty flávor much like *Marasmius*. A species of *Cantharellus* was found at Bluffton, August 25, but was not identified.

After rains *Marasmius oreades* appears abundantly on the lawn about my home near Bluffton. The fairy rings were seldom well marked. We could not say that the flavor of this species was superior to that of some larger mushrooms which are usually more easily collected. However, the large number of *Marasmius* which may sometimes occur within a small area make it possible to gather a quantity of caps without much labor. *Panus strigosus* was found near Bluffton, August 19. A single individual

grew from a decayed spot in a living tree. It was a beautiful specimen and suggested *Pleurotus ostreatus*. *Pluteus cervinus* was common both in Wells and Whitley counties, growing on very old logs, and once in a mass of rotting sawdust, in the woods. The pileus varies greatly in coloration. The species was often eaten, but unless fried crisp it has a rather unpleasant flavor. A species of *Galera*, apparently *flava*, was not rare in the woods about Bluffton, growing in clusters on decaying logs. It was cooked and the caps retained must of their bright yellow or orange color. It might be used as "trimming" for a dish of larger species.

Agaricus campestris was taken in pastures, but I did not find it in quantities as it is often found. A single specimen taken in the woods near Bluffton seemed to be *A. silvaticus*. In the same pastures and in thin woodland, often on manure, *Psathyrella* was common. All the specimens seen seemed to belong to one species, undetermined

Belonging to another order are the puffballs, the larger species of which are among the most valuable and delicate fungi. Representatives of three genera were observed this season about Bluffton. *Geaster* was found a number of times in thin woodland. *Calvatia* was found a few times. The best way to cook it is like egg plant. In former years *Calvatia* has often been observed in great abundance, occurring at the edges of woods or in thin woodland. Specimens not less than eighteen inches in diameter have been seen, and individuals eight or ten inches in diameter were not rare. A species of *Lycoperdon*, which suggested a sea-urchin with the spines removed, was common in pastures. Its diameter seldom exceeded two inches; it seemed to ripen rapidly, and it was usually infested with larvae, so none were cooked.

The Kankakee Salamander.

By T. H. Ball.

The Eel Question and the Development of the Conger Eel.

(Abstract.)

By C. H. Eigenmann.

The eel question, or "when, how and where does the eel reproduce," which is as old as history, was in part solved by Grassi, who in 1897 found

that one of the numerous species of Leptocephali found near Messina is the larva of the eel. The eel is said to seek the deeper water, where it deposits its eggs and then dies. During the past summer the eggs of the Conger eel were taken by the U. S. Fish Commission vessel Grampus on the surface of the Gulf Stream. This is the first notice of an eel egg outside of the Mediterranean. A full account of these eggs will appear in the Bulletin of the U. S. Fish Commission.

The Mounting of the Remains of Megalonyx Jeffersoni from Henderson, Kentucky.

By C. H. Eigenmann.

During the fire of the Museum of the Indiana University in 1882 the bones of the Megalonyx belonging to the University were away to be figured. In this way this specimen was saved from the destruction that overtook most of the other specimens in the collections. The trustees have recently decided to have the specimen mounted. The bones have been mounted in their relative positions without reconstruction of the lost parts. It came originally from Henderson, Kentucky.

Contribution Toward the Life History of the Squeteague.

(Abstract.)

By C. H. Eigenmann.

The Squeteague is one of the important food fishes of Narragansett and Buzzard's Bay. During the past summer I studied the habits of the young of this fish. The details will be published in the Bulletin of the U. S. Fish Commission.

A New Oceanic Fish.

[Abstract.]

By C. H. Eigenmann.

A new species of Centrolophine fishes was taken during last summer under a medusa in the Gulf Stream off Newport, R. I. It will be described in detail in the Bulletin of the U. S. Fish Commission.

A New Species of Cave Salamander from the Caves of the Ozarks in Missouri.

[Abstract.]

By C. H. Eigenmann.

While collecting in the caves of Missouri I found a species of Spelerpes rather abundant. It was taken in Wilson's Cave, Rockhouse Cave, Fisher's Cave and also near Marble Cave. It proved to be a new species which is the fourth salamander known to inhabit the caves of North America. It is a twilight species rather than a strictly cave species, being found within a short distance from the entrance of the cave in all instances.

An Addition to the Fishes Occurring in Indiana.

By L. J. Rettger.

Some Observations of the Daily Habits of the Toad (Bufo Lentiginosus).*

By J. Rollin Slonaker.

Wishing to observe the daily habits of the toad and to see if it would hibernate if kept in a warm room during the winter months, a medium-sized female toad (Bufo lentiginosus) was secured October 8th. Not having a suitable place ready for her, she was placed temporarily in a running water aquarium. Here she could climb upon some bricks and be out of the water, but it was evidently too damp, for she showed signs of uneasiness.

On the 16th she was noticed to shed and swallow her skin. This I find is not an uncommon occurrence. October 19th she weighed 59.6 g., and was transferred to a dry earth aquarium. Here she made a hollow in the soft dirt under some leaves and seemed perfectly at home.

*These observations were made at Clark University during the year 1897-8.

It was interesting to see the way she made a hollow, or buried herself. She always used the same method, pushing the dirt to each side with her hind legs and shoving herself backward with her fore legs.

She was accurate in predicting changes in temperature, appearing very hungry, and after eating, burying herself completely before a decided fall in temperature. Before rising temperature she seemed less concerned about getting her food and would not cover herself completely, usually leaving her head out as though waiting for insects.

Plenty of grasshoppers and flies were kept in the aquarium, and she ate freely each day till November 1st, when a cold wave arrived and the room cooled off during the night. This time she buried herself completely. Neither did she again appear nor show signs of life till November 29th, when she slowly emerged. This may be spoken of as a short period of hibernation.

She was in and out almost every day after this, and on December 7th she ate three flies and 2.8 g. beefsteak. In regard to their eating, toads show the same peculiarity that frogs do, in that they will not attempt to take anything that is not in motion. In order to get the toad to eat meat I threaded a small piece on a string and twirled it before her. Her attention would first be attracted by the moving object, and after gazing at it for a few seconds she would quickly run out her tongue and take it. The whole process is almost instantaneous, and one can see but a flash of light red and hear the shutting of her mouth.

After eating this amount she refused to take any more, and buried herself, as I supposed, for another hibernation. But the next day she was out again and ate a fly. On the day following she ate 12 flies and 3 g. of meat. I continued feeding her every few days and, when hungry, she would eat frozen or stale meat and thrust her tongue at any near moving object. With the exception of cold "snaps," when she would remain covered up two or three days at a time, she showed no further signs of hibernation throughout the winter.

On February 14th she weighed 88.9 g. This shows that though there was a tendency to hibernate at first, it did not manifest itself again, for an animal loses weight during hibernation. February 20th she weighed 97 g., showing a gain of 8.5 g. in six days. This rapid increase in weight was probably due to the nutritive diet of beef and to the rapid secretion of eggs.

March 2d she remained several hours in the water, and I have no doubt that she would have deposited her eggs if she had had a mate. At this time her weight was 104.7 g. Her appetite always appeared good, and though I had only meat to give her for two months, she usually took some whenever it was offered her. She always knew when she had enough meat, in fact was never very eager to take it. But with flies she was gluttonous, became excited and eager, and always had room for one more, as shown by the following day's record.

I confined a large number of flies in the aquarium with her. When she heard and saw the flies buzzing about she became very much excited and nervous, and immediately began hopping about and catching them. When thus excited, the long toes of the hind feet always had a peculiar twitching, while the remainder of her body would be comparatively motionless. It was interesting to see how rarely she missed her aim and how rapidly she ate them. At first she averaged about four per minute. Being curious to know how many she would eat, I watched and counted. When she had eaten 40 her rate began to slacken, though she was still anxious and would approach nearer when a fly was beyond her reach. At 50 she showed less energy in the chase. When 60 had disappeared she simply waited till they came within reach of her tongue, while about every third or fourth fly swallowed she would squirm and twist as though making room for one more. When she had eaten 76 I was called away. When I returned about an hour later the remaining 15 or 20 flies had disappeared. Some of these, however, may have been eaten by two or three small frogs that were confined in the same aquarium. One would think she would not want anything more soon, but the next day she was ready for more, and averaged about 40 flies each day.

The greatest weight she reached was 111.5 g. on a diet of meat and flies. It was also interesting to note that if, when she had eaten all the meat that she wanted and had begun to back into the ground, a fly with clipped wing was put before her she would quickly take it, or, if it should run out of her reach, would eagerly give chase.

One day I placed a medium-sized garter snake in the aquarium to see the effect. The toad was out and happened to be close to the side of the aquarium. As the snake crawled slowly toward her seeking a means of escape, her sides began to swell out while she slowly turned her broad back toward the snake. This made her resemble a clod of dirt more than

a toad. Evidently she knew that flight was useless and, as a place of concealment was not at hand at that late moment, her safety lay in protective coloration and in resembling a toad as little as possible.

April 20th I placed a male of the same species in the aquarium, thinking she would lay her eggs, but she would have absolutely nothing to do with him. As there seemed to be no likelihood of further development I changed them to a small park which I had prepared in a sunny part of the yard. It was mainly composed of sod, but in one corner was an area of soft earth, while in the center was a large pan of water. Here they mated at once and spent the greater part of two days hopping about, resting part of the time in the water. May 12th they buried themselves completely in the soft dirt to await the passing of a cold wave. When the cold wave had passed they emerged and the mating ceased without the deposition of eggs.

Among the things the toad was observed to eat during her captivity were ants, flies, grasshoppers, bees, wasps and many other insects which found their way within her reach. The eating of bees and wasps was followed by no ill effects except a momentary twisting or wincing. By far the greater part of her food consisted of flies and ants. These are household pests, and since the toad will average 40 or more each day it is needless to say that it is a very useful animal and one that should be protected.

The Methods and Extent of the Illinois Ichthyological Survey.

By Thomas Large.

At the present time the Natural History Survey of the Illinois State Laboratory of Natural History is working on an extensive report on the Fishes of Illinois. This is a continuation of the work begun in 1878 and carried on with many interruptions since that time by Prof. S. A. Forbes and his collaborators. It is the purpose to have every fish known to occur within the State accurately described, with complete statement of all that is known concerning food, habits and breeding, and to have the geographical distribution indicated on maps. In addition to this it is the purpose to illustrate each species with colored plates reproduced from water-color

drawings of living fish. The number of species occurring is in the neighborhood of two hundred.

At present several lines of work are in progress: At the Biological Station on the Illinois River, located in the past two summers at Meredosia, aquaria were fitted in the floating laboratory and a gasoline engine and pump on the shore made to furnish clear water in which colors of living fish were studied for color descriptions and were painted by the laboratory artists. The field work for the geographical distribution has been pushed forward by means of wagon and launch expeditions and by volunteer collectors. The launch has not been used sufficiently for extended excursions to make the experience of value to others. With the wagon two men were in the field for six weeks in the fall of 1899, making collections in the Big Vermillion and Kaskaskia rivers and their tributaries. In 1900, with the advantage of the experience of the previous year, an expedition was fitted out to make collections in eastern Illinois, with Golconda on the Ohio River as the objective point, and returning to Urbana, the starting place, through the western and central portion of the State. The equipment consisted of an ordinary covered grocer's delivery wagon and two horses, a 9x9 miner's pyramid tent, woolen blankets, a blue-flame oil stove, an aluminum cooking outfit, a supply of groceries and canned meats, five large milk cans for shipping collections home, "hand-cans" for killing specimens as soon as taken, a ten-foot minnow seine hung to fish three feet, a thirty-foot minnow seine hung to fish five feet, and a forty-yard minnow seine hung to fish six feet. The Baird nets are not serviceable in the muddy streams of Illinois, as the bag collects too much mud. The party, consisting of two men who had had experience in such work, made no attempt to secure accommodations from farmers more than horse feed and water, experience of the previous year proving it to be very expensive in time and temper. Occasionally stops were made at hotels. The entire distance covered was about six hundred miles, in six weeks' time. The cost of subsistence in field, including some repairs, was about ten dollars per week.

In preserving fish the laboratory uses 10 per cent. formalin solution for killing, in which the fish is put as soon as taken from the water. In this the fish die with fins expanded. After remaining a few hours in this solution they are wrapped in cheese-cloth and transferred to a weaker solution (about 1 per cent. to 5 per cent.), for shipment. After being brought into the laboratory they are bottled in a solution consisting of 70 parts

95 per cent. alcohol, four parts glycerine, one part of formalin, and twenty parts of water. In this solution preservation is secured without the brittleness resulting from high per cent. alcohol.

The method of this institution in caring for collections may prove valuable to those interested in museum methods. Each catch is kept separate and given an accessions number referring to all data concerning it, which is entered in an accessions catalogue. The species are then separated and bottled, with tags (similar to those attached) on the outside and inside of the bottles.

Ac. No. Sp. No. Jor. & Ev. No.	**Ac. No.** **Sp. No.** **Jor. & Ev. No.**

Those on the inside are made of ledger paper and written with lead-pencil; those for the outside are written with India ink. The tags bear accessions number, a number referring to the species list of the laboratory, and a number referring to the species number in Jordan & Evermann's "Fishes of North and Middle America." All bottles containing a particular species are racked together in series according to accessions number and placed in shelves. The racks used are wooden trays of two sizes, the larger 4½x15 inches and meant to be wide enough to hold a two-quart fruit jar. The smaller are for vials and small bottles, and are 2x13 inches. This arrangement is exceedingly convenient for ready reference to any particular fish desired.

The plan of securing collections from volunteers in localities from which materials were needed for study of geographical distribution, was put in operation in April, 1900. It commends itself because of excellent results secured and the comparatively light cost. Letters inviting co-operation were sent to high school teachers and others, in localities that had not already been covered by field work. To those responding were sent two pairs of hip boots, a twenty-five foot minnow seine, a five-gallon milk can and a quantity of formalin, with directions for catching, labeling and preserving. In return for the service each collector receives a named set of the fishes from his locality. As a result of the volunteer work of the spring and summer a large triangular area lying between the Illinois and Mississippi rivers as far north as a line from Peoria to Rock Island was quite thoroughly worked, besides several other localities. Some collectors made collections representing entire counties.

Additions to the Indiana List of Dragonflies with a Few Notes.

By E. B. Williamson.

ADDITIONS.

1. *Calopteryx aequabilis* Say. Whiting, Lake County, June 9, 1900, along a ditch which drains into Calumet River, one male; and Wolf Lake, Lake County, July 21, 1900, two males. Clarence C. Bassett.

2. *Lestes eurinus* Say. Elkhart, June 8, 1900, one female. R. J. Weith.

3. *Enallagma calverti* Morse. Lake Maxinkuckee, May 27, 1900, two males, one female. Howard North.

4. *Nasiaeschna (Aeschna) pentacantha* Rambur. Banks of St. Joe River, Elkhart, June 10, 1900, two females. R. J. Weith.

5. *Aeschna multicolor* Hagen. City limits, Elkhart, September 5 and October 12, 1899, three females, one identified by Dr. Calvert. R. J. Weith.

6. *Sympetrum albifrons* Charpentier. Bluffton, Indiana, September 9, 1900. E. B. Williamson.

7. *Libellula exusta* Say. Woods near Simonton Lake, May 15 and 20, 1900. R. J. Weith.

The State list now numbers 91 species of Odonates. Four of the above additions are due to Mr. Weith, who has also added several species, known from other points in the State, to his local list. Collections are being made at Lake Maxinkuckee, Winona Lake, Evansville, and perhaps at other points, so further additions to the list may be expected, and our knowledge of seasonal and geographical range within the State is certain to be augmented. Descriptions of two of the species mentioned above are unfortunately not found in "The Dragonflies of Indiana." They are given in the notes which follow.

NOTES AND CORRECTIONS.

1. *Enallagma calverti* Morse is of the color type of *En. doubledayi* Selys. The male may be recognized by having the superior abdominal appendages much shorter than the inferiors, in profile appearing like a short cylinder with a rounded apex which is usually distinctly notched below the middle. Mr. Morse's original description of the male of this species follows: "Abd. 23–25mm., hind wing 17–19.5mm. Prothorax greenish black, the following pale (bluish): sides; a transverse line on anterior lobe; the hind margin and a cuneiform spot on each side of

posterior lobe. Thorax with a rather narrow mid-dorsal stripe (sometimes divided by a mere line of blue, most distinct anteriorly), and a very narrow humeral stripe, wider in front, especially at the suture, and a spot on second lateral suture, black. A wide ante-humeral stripe, equal to or wider than the mid-dorsal black stripe, blue. Abdomen blue, the following black: A spot on base of 1; a transverse lunule (convex side forward, doubly concave behind) near apex and a narrow marginal band on 2; an apical spot connected with marginal band on 3 and 4; apical third of 5, two-thirds of 6, five-sixths of 7, and all of 10.

"Superior appendages short, one-fourth to one-third as long as 10, blunt, with the apex directed downward and slightly notched in profile; the upper limb thick and rolled inward, the lower limb thin, rolled inward and upward, appearing like a small, rounded, inwardly projecting shelf on the lower edge of the apex of the appendage. In profile the upper apical angle is very obtusely rounded, the lower slightly notched. Inferior appendages longer, two-thirds as long as 10, rather slender, tapering, slightly curved upward, directed upward and backward, the lower margin convex throughout." Nevada, Wyoming and other western States, and Massachusetts. This is an interesting addition to the list of *Enallagmas* known to occur in Indiana, bringing the number to thirteen, and leaving two regional species, *doubledayi* and *aspersum*, yet to be discovered.

2. *Ischnura kellicotti* Williamson sometimes has the blue ante-humeral stripe of the thorax interrupted as it is normally in *Nehallennia posita* and rarely in *Ischnura verticalis* and *Enallagma germinatum*. Individuals were taken which had the stripe continuous on one side and interrupted on the other. The species was very abundant at Shriner, Round and Cedar Lakes, July and August, 1900, found only about the white water-lily beds. Orange females were numerous.

3. Dr. Calvert has recently called attention to the fact that *Gomphus externus* as identified by Kellicott and as described in "The Dragonflies of Indiana," is in reality *Gomphus crassus*. What is said of *Gomphus externus* on pages 289 and 290 of "The Dragonflies of Indiana," excepting geographical range, belongs to *Gomphus crassus*. *Gomphus crassus* is known from Kentucky, Ohio, Indiana and Illinois. *Gomphus externus* has been taken in Illinois and westward in Nebraska, New Mexico and Texas. It must be dropped from the Indiana list, though it may be found in the State in the future. It may be separated from *fraternus* and *crassus* by the following points: In *externus* the two lateral thoracic stripes are complete, not shortened or interrupted. *Externus* has the dorsum of 9 and 10 with a yellow band as usual in *crassus*. The appendages of the male of *externus*, as figured in the "Monographie des Gomphines," plate XXI, fig. 2, as seen in profile, somewhat resemble fig. 20, plate VI, "Dragonflies of Indiana," excepting

that they are more acute and the lower edge is less angular. The vulvar lamina in *externus*, as in *fraternus*, is not constricted at the middle as it is in *crassus*. In *externus* the lamina is bifid for almost half its length; in *fraternus* it is bifid for scarcely more than a fourth of its length. *Fraternus* and *externus* are about the same in size.

On page 285, "Dragonflies of Indiana," the references should be to plate VI, and not plate VII, as there printed. Line 17 from the bottom, same page, for *Abdomen about 40 in length.* EXTERNUS, read *Abdomen about 38 in length.* FRATERNUS.

4. In "Occasional Memoirs of the Chicago Entomological Society," Vol. I, No. 1, March, 1900, pp. 17 and 18, Mr. James Tough has described and figured the appendages of the male of a very interesting species of *Gomphus* under the name of *Gomphus cornutus.* The author's description is quoted.

"Length, ♂, 55–57mm.; abdomen, 40–42mm.; hind wing, 32–33mm.

"Yellowish green, with black and brown markings. Face and occiput yellowish green, eyes posteriorly black above, yellowish below, occiput distinctly convex, notched in center and fringed with black hairs, vertex and antennae black. Prothorax black, with a geminate spot in center and a patch on each side, yellowish. Thorax yellowish green, except a narrow band, indistinct or absent anteriorly, on each side of mid-dorsal carina, also except humeral and antihumeral bands, and margins of first and second lateral sutures, all of which are brown. Legs black, front femora yellowish green below. Wings hyaline with viens black, pterestigma yellowish, and costa yellowish green. Abdomen of uniform thickness, black, a dorsal stripe or spot on segments 1–8, small and basal on 8, and a small quadrangular spot on 10, yellowish; dorsum of 9 entirely black.

"Superior appendages dull yellowish; seen from above, internal branches produced inward and backward until they meet, acute and spinose at tip; external branches short, rather broad, and tipped with a blunt spine. Inferior appendage, seen from above, slightly longer than superiors, spreading, the distance from tip to tip of outer extremities being more than twice the width of the tenth abdominal segment at base. From side view the internal branches of superiors are seen to bear a conical tooth about midway between base and apex; the inferior curving upward gradually and each branch bearing a curved spine at tip.

"Described from two male specimens, taken at Glen Ellyn, Du Page County, Illinois, one June 14, 1897, the other May 30, 1898."

Mr. Tough writes me that he thinks he has since taken the female of this species. The occiput is high, rounded, and in front is a triangular pyramid, its base bounded by the line between the vertex and occiput, and by lines drawn

from the extremities of this line to the middle point of the posterior edge of the occiput. This species will very probably be found to inhabit Indiana.

5. *Gomphus pallidus* Rambur. St. Joe River, June 8, 1900, one female. R. J. Weith.

6. *Gomphus spicatus* Hagen. Elkhart, May 20, 1900. R. J. Weith. In plate VI, "Dragonflies of Indiana," figs. 18 and 19 will *not* serve to distinguish the males of *Gomphus spicatus* and *G. descriptus*. Seen from above the superior appendages of *spicatus* have a distinct median external tooth; *descriptus* has the appendages angulated beyond the middle, but there is no tooth.

7. *Gomphus sp.* Page 294, "Dragonflies of Indiana," is a new species soon to be described by Mr. Hine.

8. With a knowledge of the nymph of *Tachopteryx thoreyi* another arrangement of the genera of the Gomphinae than that employed in the "Dragonflies of Indiana" becomes desirable. The arrangement of genera of the Gomphinae as worked out by Selys in his "Synopsis des Gomphines" and culminating with his final "Note sur la classification" in the fourth addition to the Synopsis, may be employed here for the genera taken in Indiana. The genera would then stand in this order: *Ophiogomphus, Dromogomphus, Gomphus, Progomphus, Hagenius, Tachopteryx, Cordulegaster.*

9. The genus *Nasiaeschna* has recently been established by Selys (Termèszetrajzi füzetek, XXIII, 1900, p. 93) for the species *Aeschna pentacantha* Rambur. In the key to genera in "The Dragonflies of Indiana" *pentacantha* will run out to the genus *Epiaeschna*. The genus *Nasiaeschna* is distinguished from *Epiaeschna* by the supplementary sector between the subnodal and median sectors being separated from the subnodal by one row of cells (two rows in *Epiaeschna*), by having the face excavated, by the absence of a dorsal spine on abdominal segment 10 in the male, and by the superior appendages of the male being shorter and less dilated.

10. *Aeschna multicolor* Hagen. Calvert (Odonata of Baja California, p. 509) has the following paragraph relating to the range of this species. "*Distribution.* Mexico (Cordova, Baja California), California, Texas, Dakota, Colorado, Yellowstone, British Columbia (Victoria)." In Bull. Geol. Surv. Terr. 1875, p. 591, Hagen says of it, "A decidedly western species." To find it in Indiana is a surprise. The following description is found in the Syn. Neur. N. A., 1861, p. 121. "Fuscous, spotted with blue, head blue (♂) or luteous (♀), front with a T spot, each side terminated with yellow, and a band before the eyes, black; thorax fuscous, dorsum each side with a stripe (interrupted or absent in the female), sides, each side with two oblique ones blue (♂) or yellow (♀); feet black, femora

rufous above, the apex black, anterior femora beneath; luteous; abdomen moderate, slender, cylindrical, narrow behind the inflated base; fuscous, spotted with blue (♂) or yellow (♀), segments 3–10 with two large, apical spots, segments 3–8 with two triangular spots upon the middle, and a basal, divided spot each side, segment 2 with a medial interrupted fascia, and a broad apical one, blue or yellow; superior appendages of the male black, long, foliaceous, narrow, the base narrower, inwardly carinated, straight, curved inwardly before the apex, an elevated triangular lamina above, and a longer tooth placed more inferiorly; the apical tip acute, curved downwards; the inferior appendage, pale fuscous, one-half shorter, elongately triangular; appendages of the female moderate, fuscous, foliaceous, broader; wings hyaline, those of the female towards the apex, subflavescent, pterostigma short, fuscous, or luteous (♀); membranule fuscous, the base white; 16–17 antecubitals; 8–9 postcubitals. Length 65–67 mm. Alar expanse 90–100 mm. Pterostigma 3–3½ mm." Calvert (Odonata of Baja California, p. 503) describes the superior appendage as having the apex distinctly forked when viewed in profile. "Front wings with discoidal triangle 4–6-celled, internal triangle 2-celled, rarely free, 3–4 other median cross-veins, 1–2 supratriangulars, first and sixth or seventh antecubitals thicker. Hind wings with discoidal triangle 4–5-celled, internal triangle 2-celled, 2–3 other median cross-veins, 1–2 supratriangulars, first and fifth or sixth antecubitals thicker. Male: anal triangle 3-celled; 10 with a small, median, basal, dorsal tooth and a smaller one on each side. Abdomen ♂ 47–51, ♀ 49. Hind wing ♂ 43–47, ♀ 45–47." (Calvert, Odonata of Baja California, p. 508).

11. *Didymops transversa* Say. Simonton Lake, May 15 and 20, 1900; and St. Joe River, Elkhart, May 29, 1900. R. J. Weith.

12. *Epicordulia princeps* Hagen. St. Joe River, Elkhart, July 7, 1900. R. J. Weith.

13. Males of *Sympetrum rubicundulum* and *Sympetrum obtrusum* exhibit but little difference in coloration. *Rubicundulum* has the face light brown, yellowish, darker above; *obtrusum* has the face white. The general body color of females of the two species is distinctive. *Obtrusum* and *rubicundulum* seem specifically distinct for the following reasons: both sexes offer differences in color and structure; they occur together, often in the same isolated swamp; and there seem to be no intermediate forms. On September 9, 1900, *obtrusum*, *rubicundulum* and *albifrons* were associated together in a small swamp surrounded by woodland in Wells County, near Bluffton. At a glance both sexes of *albifrons* may be recognized by the face, white below, shading above into a clear china blue, the frontal vesicle being of the same color.

14. The genus *Diplacodes* is distinguished from related genera: by the triangle of the fore wings long and narrow, free (usually) and followed by two rows of post-triangular cells (three or four rows in related genera); and by the last antenodal not continuous. *Diplacodes minusculum* could *not* be traced out by the key to genera, "Dragonflies of Indiana," p. 250. The hind lobe of the prothorax in this species is narrower than the middle lobe, sides straight, but with the hind margin emarginate, giving it a bilobed character. The supratriangular space is free and there are eight antecubitals in the front wings. In the arrangement of the genera in the "Dragonflies of Indiana" *Diplacodes* may be placed between *Pachydiplax* and *Nannothemis*. Old males of *Diplacodes minusculum*, like old males of *Nannothemis bella*, are entirely pruinose.

Eskers and Esker Lakes.

By Charles R. Dryer.

(Published in full in Journal of Geology, Vol. IX, p. 123.)

(Abstract.)

(1) The sand, gravel and till ridges around High Lake, Noble County, Indiana, with their associated lakes and kettleholes, are described and their structure and origin discussed. The till ridge is thought to be a frontal moraine, the others to be the result of subglacial drainage and the sliding or dumping of drift material into crevasses. These forms are so connected in space and related in structure as to render genetic classification difficult. The system as a whole constitutes an esker-kame-moraine.

(2) The esker system of Turkey Creek, Noble County, Indiana, is described. These sand ridges traverse the valley floor and nearly inclose the basin of Gordy's Lake. High and Gordy's lakes seem to constitute a distinct species for which the name *esker lakes* is proposed.

The paper is accompanied by two maps.

Spy Run and Poinsett Lake Bottoms*.

By J. A. Price and Albert Shaaf.

Spy Run and Poinsett Lake are located near Fort Wayne, Indiana, and to understand their history a knowledge of the region about Fort Wayne is necessary. This region is situated in that portion of the State which was formerly covered by the Erie ice-lobe. At different periods in its recession the end of the Erie ice-lobe was stationary, for a long time depositing large terminal moraines. Four of such moraines were thus formed, upon one of which, the first Erie moriane, Fort Wayne is located.

The territory in question lies on the first Erie moraine, a full description of which may be found in the Sixteenth, Seventeenth and Eighteenth Annual Reports of the State Geologist, and in Charles Dryer's "Studies of Indiana Geography." This moraine, a massive, well defined ridge with a hommocky surface, enters the State at the southeast corner of Adams County and follows the Wabash River to the northwest corner of Wells County, running parallel to the present shore line of Lake Erie; it then turns to the north and northeast and enters the southwest corner of Allen County. Increasing in width, it continues in a northeasterly direction and leaves the State at the northeast corner of Dekalb County.

As the ice continued to recede a large lake was formed northeast of the present site of Fort Wayne. The surplus waters of this glacial lake were drained into the head waters of the Wabash through the Erie-Wabash channel. Glacial Maumee Lake, as it was called, probably existed for many years, but as its eastern bank was a massive wall of ice it was doomed to destruction. As the ice melted the lake was slowly drained until it was entirely destroyed, and as the waters of the lake ebbed away its outlet dwindled and was finally silted up. St. Joseph and St. Mary's rivers, which had emptied at the point where the Erie-Wabash channel left the lake, now turned back and formed the Maumee, a slow, sluggish, meandering stream which wound itself across the old lake bottom.

The territory covered by the accompanying map lies about one and a half miles northwest of Fort Wayne, and north of the Wabash-Erie

* Credit is due Robert Feustel for his work on the accompanying map.

channel and west of the St. Joseph River. The Lake Shore and Michigan Southern Railroad passes along its eastern and the Grand Rapids and Indiana road along its western edge. It is crossed by two wagon roads, the Lima and the Goshen. Both basins are oblong, Spy Run Lake basin being about four-sevenths of a mile long and two-sevenths of a mile broad, Poinsett Lake basin being about one mile long and one-half of a mile broad.

The topography in general is smooth and level, with gentle swells here and there, characteristic of lake bottoms. The region is drained by Spy Run Creek and its tributary, the Poinsett. Numerous artificial channels are led into these streams which make the drainage more perfect. Where these channels do not occur, swamps are found as indicated on the accompanying map.

The origin of Poinsett and Spy Run lakes dates from interglacial times. These two lakes belonged to a large class of lakes which once diversified the surface of parts of the glaciated portion of the State, but which now have become extinct; irregular basins with rich soil and level bottoms remain to tell the story of their former existence. A number of these lakes were formed by glacial dams and may be divided into two classes: those produced by the irregular deposits of moranic material and those caused by the ice itself during the period of its continuance. It is quite probable that both of these causes united to form the two lakes under consideration. As the Erie ice-lobe withdrew to the northeast irregular deposits of glacial debris were left in its wake, forming knolls and basins; these basins were in the course of time filled by subsequent rains. The streams entering these basins may have been dammed by the ice front, when it occupied the position indicated by the lines *a b* on the accompanying map. The basins are enclosed at most places by rather steep banks, varying in height from ten to thirty or more feet. Between the basins and north of the stream the bank is low and gentle, running back for some two or three hundred yards. Indications of a shore line may be seen about half-way up this gentle slope, indicating a union of the two lakes.

The length of time during which these lakes existed may be inferred from the depth of the silt which accumulated over their bottoms. The accumulation of this silt has made favorable the growing of crops. Man has taken advantage of these conditions and where it is not too swampy is cultivating the soil. This is only one instance where the former

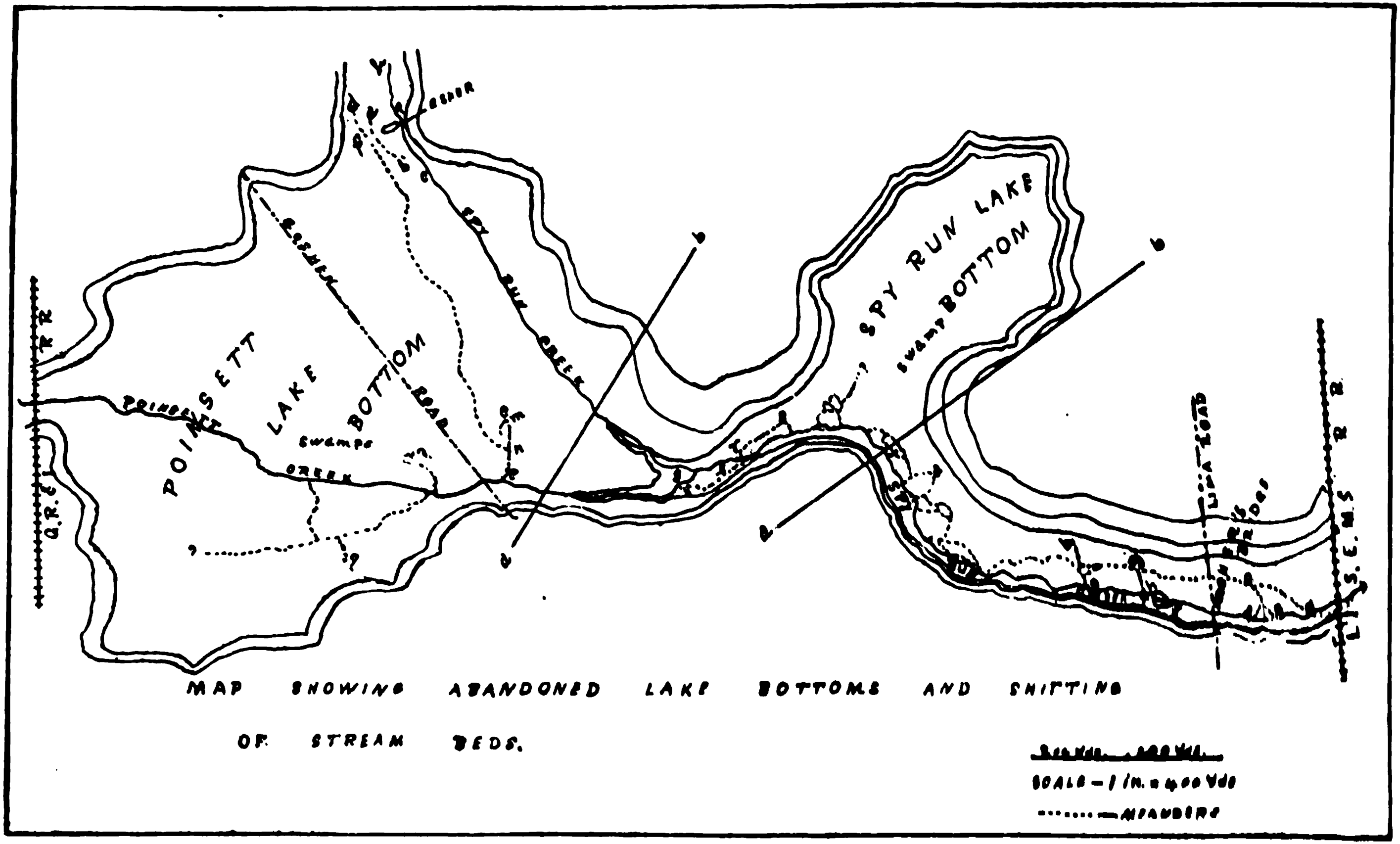
existence of glacial lakes has made favorable the conditions for man's occupancy. Maumee Lake basin, mentioned above, has a very rich soil, and yields some of the finest crops grown in the vicinity. Beyond the boundaries of our own State, and south of the line marking the farthest extension of the ice during the ice age, and south of lines marking periods of rest in its recession are many such basins; rivers were dammed, new lakes formed, and old ones enlarged, until to-day thousands of square miles of rich farming lands are found in the United States which would not otherwise have been here. The great wheat growing region and fine pasture lands of North Dakota are thus explained. "Such was the heritage which the great glacier of the ice age left as its parting gift, thus assuring the permanent prosperity of large and widespread regions of North America."

Abandoned Meanders of Spy Run Creek.

By J. A. Price and Albert Shaaf.

Spy Run Creek rises in the north central part of Washington Township, Allen County, and empties into the St. Mary's River, near Fort Wayne. It is a small, insignificant stream, but has, however, some noteworthy features, foremost of which is the marked shifting of its bed in and below Spy Run lake basin.

The head waters of this creek probably existed before the final retreat of the Erie ice lobe from the site of the first Erie moraine. The creek was dammed by the ice front, thus helping to form Spy Run Lake. The waters of the lake followed the ice in its gradual retreat and in this manner the lower extension of the creek was formed. At this time this part of the stream was probably much larger than at present. Its increased volume was due to the supply of water received from the lakes. It is impossible to say how long the stream was occupied in draining these lakes. At present, however, the stream has a well developed flood plain varying in width from two to three hundred yards. As a rule there are two or three annual overflows, during which time the waters cover a part or all of the flood plain. The depth of the water varies from six to eighteen or more inches. The strength of the current over the flooded area may be inferred from the fact that several years ago a rail fence



MAP SHOWING ABANDONED LAKE BOTTOMS AND SHIFTING OF STREAM BEDS.

crossing the bottoms was carried away. As the waters disappear from the flood plain very little sediment is left behind, owing to the fact that at this time the lower parts of the old lake bottoms are covered with water which serves as a filter. If this were not the case the old meanders that are now found on the flood plain would doubtlessly be filled up.

An inspection of the accompanying map will reveal the complexity of these meanders. In Poinsett Lake bottom the complexity is less than in and below Spy Run Lake bottom. There is one long abandoned channel (*fe*) crossing the bottoms from north to south parallel to the present channel of the stream, and entering Poinsett Creek below Poinsett bridge. The north half of this channel is well defined, having a width of three to six feet and a depth of one to three feet. Its bottom and banks are covered with a heavy growth of underbrush. Its northern end gradually decreases and finally disappears; this may be due to the fact that this part of the basin has been longer under cultivation. One hundred and fifty yards south of the north end of channel *fe*, and twenty-five yards east, lies a portion of an old meander marked *ab*. This channel is probably younger than that part of *fe* indicated by *de*. The stream left the old channel at *d* and occupied *abcg*, a part of which, *cg*, is still occupied; channel *cg* has probably been straightened by man. North of *c* the present channel is artificial, cutting diagonally through the east end of an esker at *p*. This portion as far north as was examined seems to be very young. The channel through the esker is narrow, with steep sides about ten or twelve feet high. This esker is eight or ten feet high and about one hundred and twenty-five yards long; it was connected with the uplands at *p*. Channel *fe* connects with a short, crooked channel, marked *mn*, in the southeastern part of the basin. This channel marks the lowest part of the southeastern portion of the lake bottom and was probably the last part covered by the lake waters. This last fact is indicated by the crookedness and blind ending of the channel. Between points *e* and *g* there are two or three small meanders along Poinsett Creek not marked on the map. Two abandoned meanders are found between the lakes; one, *kl*, belongs to Poinsett Creek, and the others, *rs*, to Spy Run Creek. The former is very recent, the stream having been turned from its course by the artificial channel *kg*. Below point *l*, at the sharp turn in the creek, the bank on the east and convex side is steep and nearly perpendicular; on the opposite side a flood plain

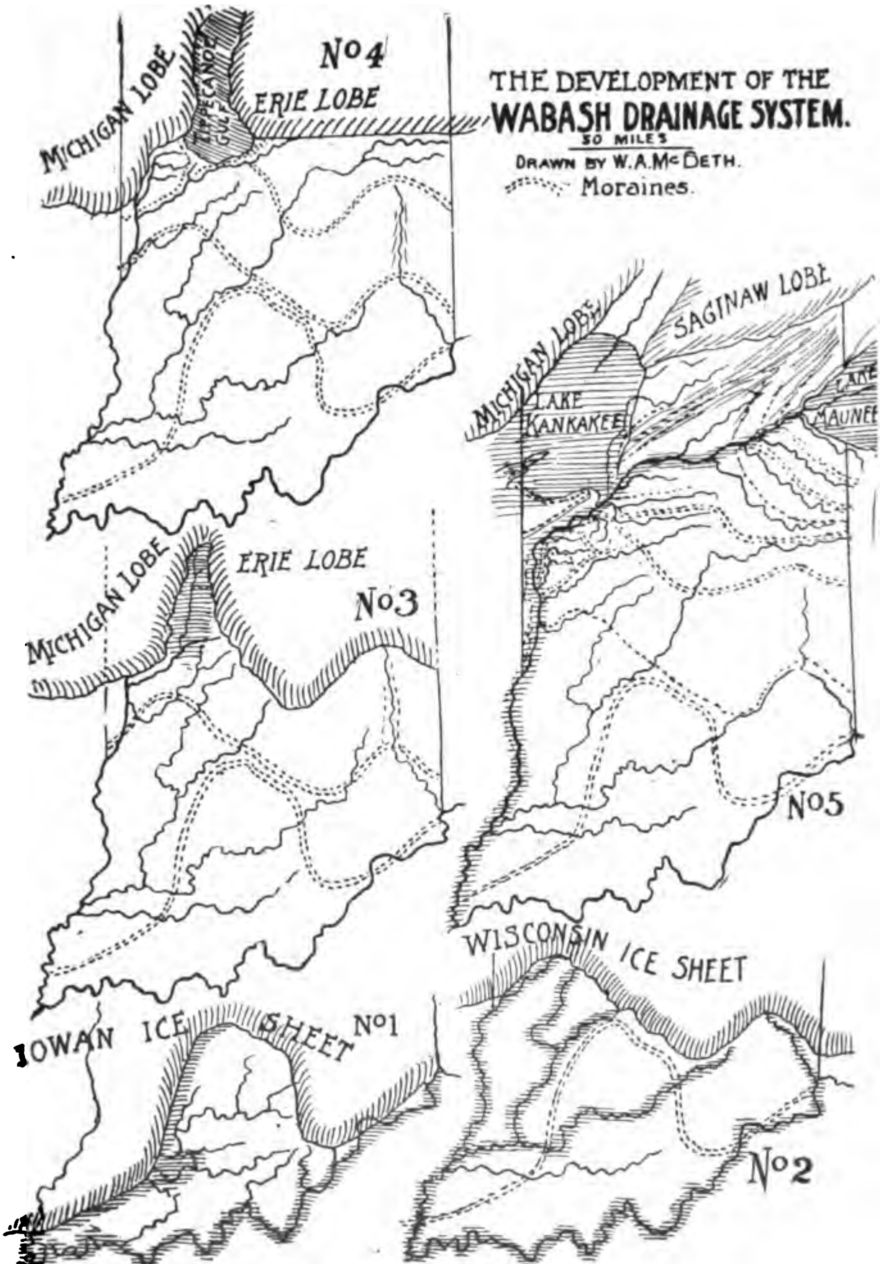
is developing. In the southwest part of Spy Run Lake bottom occurs a complex system of old channels which indicate the part of the lake last drained. This is further shown by the more or less swampy condition of this part. Below the lake bottom the system of meanders is so complex that it is impossible to trace out, with any degree of certainty, the different stages which occurred in the shifting of the stream bed. Along the north side of the flood plain there is an old channel which seems to be the oldest in the system. Near the south side, where the stream is now located, the channels are less obscured, indicating that the creek has shifted its position from north to south and suggesting that probably the complex system of meanders is due to this migration. A number of cross channels connect the old channel on the north with the present one. In developing this system of meanders the stream may have followed channel *abc*, leaving it at *c* and entering its present channel, first at *d* and then at *e* and *f*. It then probably left the old channel at *g* and crossed to its present one by the cross channel *gh*, and at *b* by channel *bo*. Above this point the complexity increases, the meanders are smaller, with a greater number of cross channels. Four very young meanders lie south of the stream, one of which, *rs*, is at times occupied by part of the stream, forming a small island.

The Development of the Wabash Drainage System and the Recession of the Ice Sheet in Indiana.

By W. A. McBeth.

The development of the Wabash drainage system has now been worked out to such an extent as to show that it is not only a subject of interest in itself, but also has an important bearing on the question of the movement and recession of the North American ice sheet. The whole of the axial stream, except a few miles near its mouth and perhaps 30,000 of the 33,000 square miles comprised in its basin, were buried beneath the ice one or more times, and there is scarcely a tributary which does not show plainly the effects of the influence of the ice sheet in determining its course and its drainage area.

Along the line of the lower Wabash, the earlier ice approached within twelve or fifteen miles of the Ohio River, and almost to the limit of ice


THE DEVELOPMENT OF THE
WABASH DRAINAGE SYSTEM.
30 MILES
DRAWN BY W. A. McBETH.
Moraines.
No 4
MICHIGAN LOBE
TIPPECANOE GULF
ERIE LOBE
No 3
MICHIGAN LOBE
ERIE LOBE
SAGINAW LOBE
MICHIGAN LOBE
LAKE KANKAKEE
LAKE MAUNEE
No 5
IOWAN ICE SHEET
No 1
WISCONSIN ICE SHEET
No 2

movement the evidence of obstruction and readjustment appears. Near the southern limit of the drift the Patoka River is an example of a stream made up of several sections. Three northwestward flowing streams were obstructed in their lower courses by the ice, and compelled to seek westward outlets across divides along the ice border. The lower course of White River was also obstructed and the part within the unglaciated area ponded up in its deep valley through the Knobstone. In the main stream and in many of its tributaries temporary lakes were formed which overflowed over the ice or along the ice border.

West White River is conspicuously a border drainage line as far up as northern Monroe County, as shown in its course through Owen, Greene and Daviess counties.

The position of the Shelbyville moraine indicates that Raccoon Creek was in existence through half its length before the Wabash was uncovered north of Vigo County. Further recession northward brought Sugar Creek into existence. This stream is very distinctly of border drainage type, as shown by the prominent moraine along its north bank from its mouth to southwestern Clinton County. After further recession of the ice sheet Coal Creek took its way north of a region of morainic uplands, until it came against a strong north and south moraine which deflected its north branch in a great bend, remarkably like that of the Wabash. The part of this stream above its great bend is comparatively meandering and its valley, which is very shallow, is in marked contrast with the deep, broad valley below the bend. South Shawnee Creek runs west parallel with North Coal Creek and bends to the north within a mile of where this creek bends to the south. A broad, marshy valley connects the two bends, indicating that South Shawnee Creek formerly turned south. These creeks have their sources at the crest of the kame moraine, which runs northwest from Darlington, Montgomery County, toward Independence, Warren County, and are guided by moraines trending east and west. To the east of the Darlington-Independence divide, the streams flow northeast in a direction opposite to that of the Wabash. They are turned northwest into that stream by a moraine running southeast from a point about five miles south of Lafayette to the southeast corner of Tippecanoe County. The three forks of Wild Cat Creek coming from the east turn north along the western side of a moraine, which lies along the western edge of a till plain rapidly rising to the east. This moraine, in my opinion, is the strong outer moraine of the Erie lobe and marks

the westward limit of Erie ice as a separate lobe. The Wild Cat creeks, above their northward bend, are bordered along their northern bluffs by weak, but distinct, moraines.

Returning to the Wabash, at the great bend we find it following the south side of a strong moraine from the mouth of Tippecanoe River to the point of its southward deflection. The drainage on the south side of the stream through this section was all to the south and west previous to the recession of the ice to the north side of the river. Above the mouth of the Tippecanoe the Wabash becomes probably a distinctly terminal drainage stream of the Erie lobe, and its tributaries have come into existence in pairs on opposite sides of the main stream as the ice withdrew toward its source. The head waters of the southern tributaries have in several instances been pirated by the stream to the south and west of them, as in the case of the deflection by the Mississinewa of a tributary of West White River north of Muncie, and the capture of the Salamonie by the Wabash above Ceylon. The development of these upper tributaries and the former connection of the St. Mary's and St. Joseph rivers and the glacial Maumee Lake with the Wabash by way of the broad valley of Little River extending from Ft. Wayne to Huntington have become familiar facts through the investigations made by Dr. C. R. Dryer and published in the Sixteenth, Seventeenth and Eighteenth Reports of the State Geologist of Indiana. The Tippecanoe River, after the manner of the upper tributaries of the Wabash, may be paired with the Wild Cat Creek. Below the great bend of the Tippecanoe. in Starke County, it drains the western edge of the Erie drift; above that bend it receives its water supply from the Saginaw drift. From its mouth to New Buffalo, ten miles north of Monticello, it has a deep valley (100 feet at Monticello) and varying from one-half of a mile to a mile in width. Above this deep portion, the character of its valley changes rather abruptly to a very narrow and superficial channel, not much too large to carry its flood waters. This shallow valley is remarkably meandering, much of the general course being originally guided by sand ridges. The lower portion of the Tippecanoe was evidently the former outlet of a lake of considerable extent, which covered the country north of Monticello. The earliest lake area may have extended southward to the immediate vicinity of the mouth of the river, where the strong moraine running along the north bluffs of the Wabash changes abruptly near the Tippecanoe battleground to a chain of low gravel mounds, which continue

across Pretty Prairie, a gravelly terrace plain, a distance of three miles to the mouth of the Tippecanoe River. The crest of this moraine at the Soldiers' Home, four miles north of Lafayette, is higher than the surface of the plain at Monticello or Winamac, and the gap has the appearance of having been once the passageway for a large stream from the north. The part of the Tippecanoe from New Buffalo to the great bend is the newest part of the stream. It established its meandering course among the sand ridges along the eastern side of the lake bed and connected the part above the bend, which formerly flowed into the lake, with the part which was the lake outlet, giving an interesting example of a spliced stream.

The description of the development of the drainage of the Wabash system has been traced to the above extent in order to group its main facts together and bring them to bear on the question of the manner of recession of the ice sheet from its basin and some of those basins adjoining it.

Several writers on problems connected with the drift area seem to assume that the ice sheet could not have receded in any other way than from west to east. The Kankakee Lake, the western Indiana bowlder belts and various other problems are perplexing problems on this assumption. While in a general way the view is doubtless true that the recession was in this direction, the solution of several interesting points connected with Indiana drainage becomes simple by the acceptance of good evidence that in western Indiana the recession was from east to west.

The Michigan, Huron and Erie depressions were doubtless lines of southward and southwestward movement which became filled with ice and overflowed before the country between was invaded. Gradually the ice accumulated and covered the crests of the divides, becoming a confluent area with smooth, regular slopes on the surface, but conforming generally on the under side to the relief of the rock surface below. Valleys and low tracts of the preglacial surface would become lines of more rapid flow and the ice would move farther forward along these lines than elsewhere. The arrangement of the moraines in Illinois, Indiana and Ohio shows the influence of this lobate movement to the limits of the drift of any period.

The curving to the north of the glacial boundary in Indiana is easily explained by the stranding of the ice along the north and south belt of resistant rocks, including the Knobstone in that part of the State, while

the lower regions to the east permitted the advance of the ice to the Ohio River, and on the west the ice crept south almost to the mouth of the Wabash in Indiana and nearly to the mouth of the Ohio in Illinois. The last general invasion sent ice much further south in Illinois than in western Indiana.

The recession of the ice was in general the inverse of its advance. It melted away on the divides, became differentiated again into lobes, which gradually withdrew up the depressions along their lowest lines. The evidence is abundant to show that the last ice sheet disappeared along a line running east of the Wabash River from Terre Haute through Crawfordsville to Lafayette before the region traversed by the present river below Lafayette was uncovered. Probably this interlobate melting continued northward along the line of the lower Tippecanoe and upper Kankakee into Michigan.

The evidence that the last ice in western Indiana occupied the region south and east of the great bend of the Wabash after it had receded from the country farther east is embraced in the condition and arrangement of numerous moraines, many overflow channels, and temporary lake beds with their traversing stream lines of different ages.

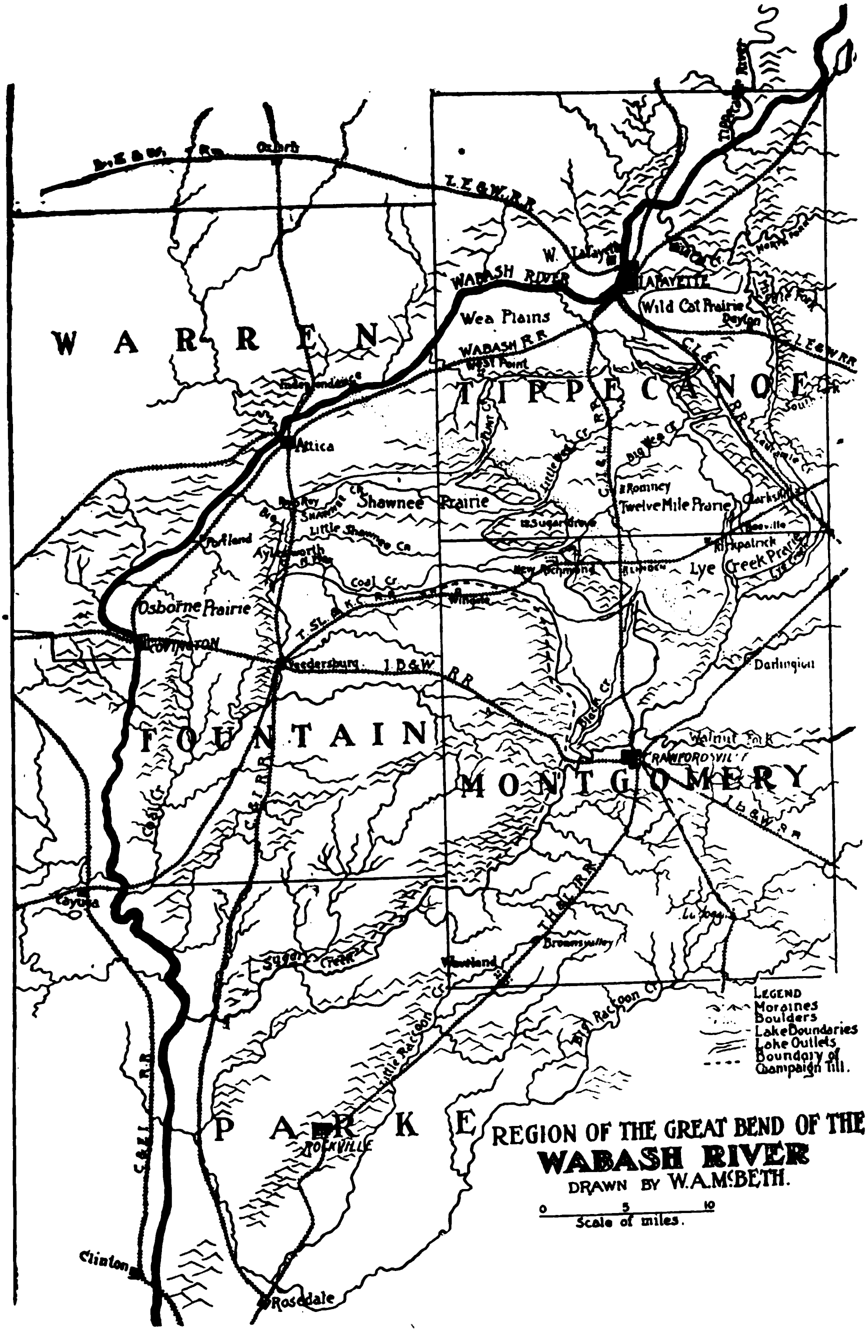
The moraines along Raccoon Creek, Sugar Creek, the southward flowing part of Coal Creek and the east and west ridges extending across Fountain County, together with a high, sharp, and in some places very narrow moraine running east from the town of West Point, Tippecanoe County, to a point five or six miles southeast of Lafayette, do not seem to have been overridden or much disturbed since they were laid down. They were deposited by ice from west and north of the present river line and according to their shape and trend, evidently by the Lake Michigan lobe. The heavy moraine north of the Wabash and west of the mouth of the Tippecanoe has not been overridden. It is a moraine of the Michigan lobe called, by Mr. Frank Leverett, the "Bloomington moraine," and extends twenty-five or thirty miles farther northeast than he has mapped it.* Moraines trending northwest and southeast in southern Tippecanoe County seem to be outposts of minor advances of the ice from the Erie lobe around the southern edge of the Michigan lobe. These ridges run across the line of division between the lobes and have numerous gaps through them.

* See map pp. bet. 24-25, in his late U.S.G.S. Monograph XXXVIII on the Illinois Lobe.

These gaps and old channels are numerous and conspicuous in northern Montgomery and southern Tippecanoe counties particularly. Lye, Potato and Black creeks, flowing south into Sugar Creek, have their present sources at gaps in the divide to the north, where they approach in some cases within a few feet of the sources of streams flowing northeast and north into the Wabash.

A map and discussion of this region was presented to this body at its last winter meeting, and the points reviewed are referred to in connection with the present question of recession. The Independence-Darlington moraine has at least six overflow channels across it, from which the water formerly flowed south between this ridge and the eastern edge of what Mr. Leverett calls the "Champaign Till Sheet" in his report mentioned above. This till sheet approaches in the vicinity of New Richmond, Montgomery County, within a mile of the Independence-Darlington ridge, the space between showing long stretches of very fertile level prairies, doubtless the beds of former lakes. North Coal Creek now flows west along the northern border of this portion of the Champaign till sheet, to the great bend where it flowed against the eastern edge of the Michigan lobe and was turned south within six miles of the present line of the Wabash and compelled to make its way twenty-five miles to the south before joining it. South Shawnee Creek turned south then and joined Coal Creek at the bend through the marshy sag now connecting their abrupt elbows.

A comparison of the altitudes of these gaps with the altitudes of stations along the Cloverleaf Railway (T., St. L. & K. C.) shows very well the westward slope of the country along the divide between the streams flowing north into the Wabash and those flowing south into Sugar Creek. In the order of their occurrence from east to west the stations and their altitudes are: Clark's Hill, 818 feet; Beeville, 792 feet; Kirkpatrick, 787 feet; Linden, 783 feet; New Richmond, 776 feet; Wingate, 776 feet; and Aylesworth, at the bend of Coal Creek, on the C. & E. I. R. R., 644 feet. Aylesworth is 150 feet lower than Beeville and 130 feet lower than New Richmond. The water then must have been held in by a barrier approximating 150 feet in height to account for the overflow channels south along the eastern edge of the Champaign sheet. The altitude of the overflow channels toward the south would give the lake lying north and east of the divide a depth increasing with the northeastern slope to more than 100 feet at Dayton in eastern Tippecanoe County, whose altitude is 673 feet, as compared with 787 feet at Kirk-


WARREN
TIPPECANOE
FOUNTAIN
MONTGOMERY
PARKE
WABASH RIVER
Wea Plains
Wild Cat Prairie
Shawnee Prairie
Twelve Mile Prairie
Lye Creek Prairie
Osborne Prairie
Lafayette
W. Lafayette
Attica
Covington
Veedersburg
Crawfordsville
Darlington
Waveland
Rockville
Rosedale
Clinton
Cayuga
Wingate
New Richmond
Romney
Kirkpatrick
Dayton
West Point
Sugar Creek
Coal Cr.
Big Raccoon Cr.
Little Raccoon Cr.
Legend
Moraines
Boulders
Lake Boundaries
Lake Outlets
Boundary of Champaign Till.
REGION OF THE GREAT BEND OF THE
WABASH RIVER
DRAWN BY W.A.McBETH.
0 5 10
Scale of miles.

patrick or 776 feet at New Richmond. The recession of the ice from the present line of the Wabash removed the back wall from this arrangement of features and the gradual cutting down of the valley of the Wabash eventually drained the larger and several succeeding smaller lakes and permitted the establishment of the present drainage of southeastern Tippecanoe County.

It may now be said that an extension of the same process further north and the disappearance of the ice along the line of the Tippecanoe to its great bend, and along the upper Kankakee, while the ice still occupied the country to the west, would make quite simple the problem of Lake Kankakee and other temporary glacial lakes.

The arrangement of moraines along the north bank of the three forks of Wild Cat Creek together with the pirating of the heads of several southern tributaries of the Wabash indicates a comparatively rapid northward recession of the southern edge of the Erie lobe.

The region embraced in the Wabash basin still doubtless presents in almost every county interesting problems for the intelligent investigator who may care to look for them, and the facts and opinions here set forth are intended as suggestions to be verified or rejected by others or myself, after further investigation.

Note: In No. 3 and No. 4 of maps illustrating the development of the Wabash drainage system I have indicated the probable line of interlobate melting. I have suggested the name Tippecanoe Gulf for this reentrant area.

A Theory to Explain the Western Indiana Bowlder Belts.

By W. A. McBeth.

The proximity of the bowlder belt southeast of Independence, Warren County, to the moraine which parallels it a little distance to the west, is a marked relationship. The bowlders lie on and along the foot of the eastward slope of the moraine. Where the slopes are gentle the belt widens out, and on the abrupt slopes the width decreases and the bowlders are more numerous. There are also patches of them on the ridges and knolls that lie to the east at levels lower than the main divide. Bowlders are not infrequent anywhere in the whole of western Indiana, but are

considerably more numerous in the belt than elsewhere. They are also more numerous about the eastern ends of the sags or low valleys through the Independence-Darlington moraine. They are very numerous in the valley of the Wabash at Independence where the belt crosses the river. Here in the lowest part of the valley, and on the terrace north of the river, they lie so thick over the surface that a man might cross a field stepping from one to another. The belt is not continuous, but there are gaps both south and north of Independence.

A number of theories to explain these bowlder belts has been proposed. The theory which was in some way suggested to Mr. T. C. Chamberlin, that they are beach lines, was dismissed by him with scant notice. His objections to the theory were that the slopes are all to the southwest and that there could be no ponding of great extent in front of the ice sheet. The general slope indeed is to the west, but the slopes on which the bowlder belts lie are eastward slopes. Further, the belts lie at the western side of areas that have been for considerable periods of time covered with water.

The belt southeast of Independence is conspicuously related to the western border of such a lake area. The belt northwest of the Wabash follows quite closely the western curve of the border of the south arm of Lake Kankakee, as mapped by Mr. Leverett.*

This belt is not necessarily or probably a continuation of the belt south of the Wabash River. Nor are the bowlders lying across the valley at Independence certainly to be correlated with the belts to the north and south. All the bowlders were probably deposited by floating ice, at the western shallow edges of the lakes, where bergs and floe ice would strand and drop their loads. They were deposited in the river valley at Independence while the river was at that point the outlet of an extensive lake held in the deep preglacial valley extending upstream to the mouth of the Tippecanoe River and of unknown width and extent. This lake has since been filled by gravel deposits, but bergs stranding about the outlet may have deposited the bowlders at the top of the terrace, and they have since dropped to lower levels as the valley was cut deeper. Reasons for believing that the ice sheet disappeared from the region to the east of the present southward flowing course of the Wabash and along the Tippecanoe River are stated in the article on "The Development

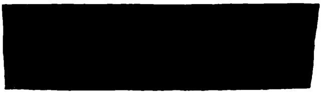
* In his Monograph on the Illinois Lobe, pages between 24 and 25.

of the Wabash Drainage System," in this volume. The westward wall of ice along this Tippecanoe Gulf helps to explain the laking which was due to the obstruction of drainage toward the west.

Commenting on the theory proposed, Dr. C. R. Dryer mentioned that the Iroquois Beach in New York is thickly strewn with bowlders in much the same way as the Indiana belts mentioned.

Aids in Teaching Physical Geography.

By V. F. Marsters.



Harper's Ferry Sheet.

The past decade has witnessed a growing interest in and a corresponding advancement along rational lines in geography, now justly regarded as a technical science. One of the pertinent reasons for this is that the seeker after knowledge, long before the college is reached, is becoming cognizant of the fact that the mere accumulation of geographical facts does not constitute geographical knowledge in the scientific sense. To know *where* the Blue Ridge is, is simply memorizing a *fact;* to know *what* it is, and, still further, to find out for one's self something about the sequential history of this topographic feature, constitutes *real geographic knowledge.* The former calls for observation and the sole exer-

cise of memory; the latter demands that we not only accumulate facts, but that we seek a rational explanation of the facts observed. And just so far as we can see the relationships of the factors concerned in a geographical problem, and the role each has played in producing the observed results, to that degree have we gained real and useful scientific knowledge.

It was with this fundamental principle in mind that I have set about to prepare some geographical helps to attain this end. Any piece of apparatus such as a geological model, or map which properly expresses an evident relation between the geology or rock structure and the topography provides good material from which may be gained genuine geographical knowledge. Such material, however, is often in poor form and shape for laboratory use, and more often quite useless for lecture purposes, the scale being too small, or facts not well expressed. The material I describe below is intended primarily for use in lecture work. It consists of a lantern slide of a model representing a type of land form, and showing at once the relief of the land as well as the rock structure in two cross sections. With the picture of a model which brings out clearly the relations of structure to topography, and all the larger features of adjustment of drainage to structure, the lecturer can actually show up the facts as well as the arguments leading to his interpretation of the actual history of the land form discussed. Such details as could not be shown on ordinary maps may be clearly depicted by this method of illustration.

The data used in the construction of the illustrated model were gathered from the Geological Atlas sheets published by the United States Geological Survey. The area selected is that covered by the Harpers Ferry sheet. From the data therein contained, a model was constructed on the scale of one inch to the mile, vertical scale one inch to sixteen hundred feet.

The method used in the construction of the base may be aptly termed the contour method. The course of procedure was as follows: The topographic sheet was first enlarged to the desired scale. In the case of Harpers Ferry it was enlarged from two miles to the inch to one mile to the inch. The culture in addition to the topography was also transferred to the enlarged sheet and the whole traced on tracing cloth. The next step was to determine the vertical scale which would give the most expressive and yet close approach to the natural appearance of

the topography when combined with a given horizontal scale. In the illustration selected it was found that sixteen hundred feet to the vertical inch gave the most effective result. Inasmuch, then, as the contour interval used on the topographic sheet was one hundred feet, and we wished to adopt in the construction of the model the scale mentioned above, it follows that sixteen sheets of strawboard, one-sixteenth of an inch in thickness, placed one upon another, would provide the vertical scale desired. This determined, each contour, beginning with the lowest, was then traced on separate sheets of strawboard, carefully cut out, piled in their proper succession and location, and tacked to a well seasoned wooden base or platform. The model at this stage presented a terrace-like appearance. This objectionable feature so often seen on geographical models, was easily obliterated by covering the entire surface with a sheet of clay, taking care of course to preserve as much of the details of relief as was shown on the original map. A plaster negative was next made from the original and from it a final positive was prepared. After thorough drying, the surface was painted a dead white. The partings or the contacts between adjacent formations as indicated on the geologic sheets referred to above, were carefully plotted and drawn on the white surface, in well defined black lines, sufficiently broad to be clearly photographed on a scale small enough to be transferred to a lantern slide. Before taking this step, however, another addition was made to the model. Two cross sections expressing the structural geology, one from east to west and the other from north to south, the former located on the south end and the latter along the east side of the model, were prepared. The outline of the topography along the respective sections was also traced on each section and cut out. These sections were then fastened to the end and side of the model in their proper vertical position, so that the relief, partings and structure were correctly correlated. The model was then photographed in a tilted position so that both sections could be clearly seen and the relief at the same time well expressed by obtaining moderately strong light and shade. It is especially important that the lines of contact be clearly brought out, as they determine the limits of the formations to be subsequently colored. A slide was next made from the negative and sent with a copy of the Harpers Ferry Atlas sheet to a photographic artist, with instructions to color the slide, adopting of course, so far as might be feasible, the same scheme of colors as appear on the geologic sheets.

Use.—In conclusion it should be said that a trial of the first slide made it evident that the use of such illustrations would materially increase the facilities for teaching geography and increase the educational value of the work accomplished. Such material may not only help the lecturer to avoid technical description of features usually not illustrated at all, when simplicity of treatment is demanded, but with this aid he is enabled to show his class or audience a mass of facts upon which he bases his interpretation of the phenomena discusssed. By this means, the lecturer may even treat somewhat technical and involved problems so that they may be made easy to comprehend, and, most important of all, whatever geographical knowledge be absorbed, is properly attained through the exercise of observation, comparison and deduction. For just so far as the student subjects himself to such mental discipline, in the same degree does he acquire a scientific knowledge and the power of analysis that is lasting and of true educational value.

The picture attached below is a copy from the negative from which the lantern slide was prepared.*

River Bends and Bluffs.

By Wm. M. Heiney.

Bends and bluffs of rivers are interdependent. While under the universal river law of taking the course of least resistance, the embryonic bluff must first exist, the matured bluff is the product of the river's course. But, early the relation begins shifting, and the bend becomes the consequence of the bluff. Again, however, the bend batters down the bluff, so that the relations first attained are repeated.

The above propositions are verified by tracing the historical relation of the bluffs and bends in a very crooked section of about fifteen miles of the Salamonie River, found in the southern part of Huntington County, Indiana.

Fig. A represents the stream in its present course, with the bluffs and their connecting ridges, which define the territory over which the stream

*I will be glad to correspond with any person who desires to obtain copies of these slides for school or college collections. Others are being prepared.

has been shifting its course during the past few centuries. The dotted lines indicate the location of ridges, which when carefully traced are found to mark one or the other of the banks of the more ancient stream.

I will return to this after detailing some of the operations of the agencies which I have observed during the past quarter of a century.

At z, Fig. A (enlarged section, Fig. C), is a small tableland (t), which twenty to twenty-five years ago was broader and extended upstream five to seven rods further than it now does. In half a century more, at the present rate of erosion, the part of the tableland still remaining will all have disappeared, and what is now a well defined ridge will have become a bluff. Both the ridge and the tableland are covered with forest trees, while the bluff for a mile up the stream, and from the point of contact (u) of river and ridge, is barren, indicating constant and rapid weathering, and consequently a gradual northward movement of the stream bed. I shall return to this again after giving fuller observations of similar changes at the bend y, Fig. A.

This bend is best studied in Fig. B. More than twenty years ago I was familiar with the bar, n', lying under but upstream from the sycamore tree, v, which still stands. Then the bar, n' (see n, Fig. D), was the only one, and formed the river bank. It was of pure, washed sand and had no vegetation whatever growing upon it. It now has willow and sycamore trees five or six inches in diameter. Now, also, there is another bar (w' in Fig. B and w in Fig. D), which is the one bordering the river, of pure, washed sand and without vegetation.

These facts stimulated further investigation and furnished the key to deeper secrets. I examined the topography farther east and found a considerable elevation about forty feet wide (m' in Fig. B and m in Fig. D), and succeeded by a lowland; then, again, another rise, l (l'), extending eastward for two hundred and fifty feet, and in turn succeeded by a sink, better marked than any of the others (see k in Fig. D and k', Fig. A). Both these bear evidence of being former bars, and their relative ages are evidenced by the trees, which I have tried to indicate in my drawings, by trees and stump. Those trees which have grown upon m (m') are not larger than fifteen inches in diameter, while those upon l (l') were large forest trees, many three and four feet in diameter. This last is all cleared of its timber now and is a well cultivated field. In Fig. A, n'', m'', l'', and k' do not represent the correct relative distances, only relative position.

From f to y, Fig. A, is a barren bluff and gives evidence of the river bed's gradual southward movement, but at y (enlarged section of which is found in Fig. B) the westward movement of both bed and bluff is quite marked. Within the time of my own observation, I am certain that from twelve to fifteen feet of the bluff, which is some fifty feet in height, has disappeared. A year ago a mass of earth (see g in Fig. D) 6x8x30 feet dropped down five feet at the north end, but still clings to the surface at the south end. It is rapidly yielding to the elements, and two years hence no trace of it will remain. As this bluff moves westward the one at x is moving eastward at about the same rate of speed. Thus in the course of two thousand years will occur a phenomenon rarely found on this stream, i. e., a waterfall or rapid—a fall of thirteen feet in one thousand, and possibly a canyon, also.

Yet there will still remain enough bend to renew the northward movement of the channel and in time the highland of the "Heiney Bend" will disappear—the stream will bend far to the north—the bottom lands will lie south of the stream, with the adjoining bluff of the river on its north bank. The newly formed bottom lands will lie much lower than those of the "Sheet Bend" at present.

Now let us leave the present and future of the stream and go back to its past. Following the old bed as indicated by its right bank (the dotted line, pq, in Fig. A, and p′, Fig. B), and taken in relation with some sink holes (o in Fig. A and o′ in Fig. B), along the foot of the ridge, it is evident that the old bed crossed its present bed at p and q, and that the "Shutt Bend," which is extending itself southward, was once much smaller than now. This bend has been greatly eroded. It is considerably lower than its neighbor on the west, the south part of the "Heiney Bend," and as a consequence does not bear the remains of as ancient river beds as the latter. In Fig. B, I have endeavored to show the low places in the surface by shortening the lines which indicate the bluffs and ridges; thus r′ and s′ correspond with the dotted lines r and s in Fig. A, and doubtless locate the successive channels of the river before it settled down between the ridges and bluffs which bound its present immediate basin, or what the farmers term the "first bottom," more generally recognized as the "lower terrace." From the present topography it is certain that after the river left its channel, r, and before it took its present general course between the ridges, it crossed at s, and again at h. A far

more ancient channel than any of these, however, is found from a to b. This rises on much higher ground at a and though not so well marked as the more recent channel its lower course, as it nears b, has become well emphasized by recent drainage of the adjacent country.

The stream will probably forage its way to all the bounding ridges and denude them—render them bluffs—before cutting its new channel, xy, when it will again leave them to weather themselves into symmetrical shapes, dress in forest verdure and present history as well as future possibilities, which speculation in this age is unable to suggest.

Notes on the Ordovician Rocks of Southern Indiana.

By Edgar R. Cumings.

The present paper dealing with the stratigraphy of the Ordovician of Indiana is preliminary to a more complete report on this interesting series of rocks, which the writer has in preparation. In the latter paper an extended discussion of the faunas of these rocks will be possible. At present the study of the large collections obtained is not sufficiently advanced to admit of any such presentation. It is therefore proposed to give here practically nothing but the notes taken in the field, with such supplementary remarks as may seem necessary.

The work of the Indiana University Geological Survey during the field season of 1900 covered the counties of Dearborn, Switzerland, Ohio and Jefferson. The following sections were measured and from most of them extensive collections were made:

Section in Kentucky opposite the mouth of the Miami River (5.9A):*

	Ft.	*In.*
51—Covered to top of hill	112	..
50—Fragments of Strophomenoid shells	..	7
49—Shale	1	..
48—Limestone. Fragments of Brachiopods	..	6
47—Shale	1	..
46—Hard limestone with *Rafinesquina*	..	5
45—Shale	2	4
44—Limestone. *Rafinesquina* abundant	..	5
43—Covered, probably shale	17	6

* This section in Kentucky is given because it is the farthest east of any section showing exposures of rock to river level.

	Ft.	In.
42—Shale	2	6
41—Limestone	5	2
40—Shale with thin layers of sandstone	8	6
39—Limestone with Bryozoa and *Rafinesquina*	..	3
38—Mostly shale	10	8
37—Crystalline limestone. *Rafinesquina* and *Dalmanella*	9	..
36—Shale	2	3
35—Thin layers of bryozoal limestone	1	..
34—Shale	6	9
33—Bryozoal limestone	..	6
32—Shale	7	..
31—Limestone, shale at top. *Dalmanella* (aa)	..	7
30—Covered	42	..
29—Compact highly crystalline limestone; few fossils	..	3
28—Shale	2	9
27—Highly crystalline limestone containing fragments of *Asaphus*	..	7
26—Shale	..	5
25—Compact limestone containing *Dalmanella*	..	5
24—Covered, probably some limestone	16	..
23—Brachiopod limestone (?)	..	4
22—Covered	8	4
21—Limestone. *Rafinesquina* and Trilobites	..	3
20—Shale	6	4
19—Covered (probably shale)	16	..
18—Limestone (in place?)	..	6
17—Shale	10	8
16—Limestone. Bryozoa, *plectambonites*	..	3
15—Shale	1	..
14—Limestone. *Balmanella, Plectambonites*	..	2
13—Shale	..	7
12—Sandstone	..	3
11—Shale	2	9
10—Limestone with *Dalmanella*	..	3
9—Shale, possibly some sandy layers	5	..
8—Hard compact limestone, very few fossils	..	5
7—Shale	6	..
6—Layer of crystalline, crinoidal limestone	..	..
5—Partly covered, mostly shale	33	..
4—Sandy layer with *Trinucleus concentricus*	..	1
3—Shale	5	4
2—Limestone containing *Dalmanella* (aa*)	2	3
1—Shale to level of Ohio river	6	2
Total section	361	..

* a, abundant; aa, very abundant; c, common; r, rare.

In the high hill just south of Aurora the rocks are exposed as follows (§1.35 A):

	Ft.	In.
45—A few layers at the top contain *Rafinesquina*, the remainder covered	60	..
44—Limestone with *Platystrophia, Hebertella, Rafinesquina, Monticulipora*, etc.	16	..
43—Highly fossiliferous limestone. *Platystrophia, Hebertella*, etc.	1	6
42—Shale with occasional layers of limestone	4	4
41—Limestone with *Zygospira* and Gastropoda	3	4
40—Limestone. Rafinesquina (aa)	1	6
39—Shale	..	8
38—Same as 32	..	4
37—Covered	1	8
36—Coarsely crystalline highly fossiliferous limestone	..	2
35—Covered	6	10
34—Same as 32	..	3
33—Shale	1	8
32—Coarse-grained fossiliferous limestone, with yellow argillaceous material in streaks	..	8
31—Shale	..	6
30—Limestone. *Zygospira* and *Hebertella*	..	6
29—Shale and shaly limestone	1	3
28—Very fine grained compact limestone, no fossils	..	3
28—Shale	1	..
26—Limestone intercalated with shale	1	6
25—Shale	..	9
24—Sandstone	..	3
23—Covered	2	6
22—Coarse-grained, blue limestone, mottled with brown. Large thick-shelled *Rafinesquinas*	..	8
21—Shale	..	8
20—Hard blue crystalline	..	8
19—Covered	1	4
18—Limestone (in place?)	..	10
17—Covered, probably limestone	10	8
16—Steel-blue finely crastalline limestone with *Rafinesquina*	..	5
15—Shale	..	8
14—Shaly sandstone	..	3
13—Coarse crystalline limestone	..	8
12—Shale	..	6
11—Compact limestone, gray mottled with yellow	..	6
10—Shale	..	9
9—Compact fine-grained drab limestone. Few fossils	..	9
8—Shale	1	..

	Ft.	In.
7—Compact, hard, coarsely crystalline limestone containing *Rafinesquina*	..	7
6—Shale	..	10
5—Blue crystalline limestone. *Rafinesquina*	..	4
4—Shale	.	6
3—Crystalline limestone with *Rafinesquina*, *Platystrophia*, *Monticulipora*, etc	..	6
2—Talus with immense number of fossils	85	..
1—Covered to the level of the river. *Dalmanella* abundant in the loose pieces near the bottom	180	..
Total section	393	..

On the north side of Laughery Creek, opposite Hartford, the following section was measured: (§ 1.36 A.)

	Ft.	In.
34—To top of the hill, loose pieces of limestone containing *Platystrophia* and *Hebertella*	60	..
33—Thin bedded limestone	..	5
32—Covered	2	8
31—Same as 29	..	3
30—Shale	..	4
29—Limestone with argillaceous streaks	..	5
28—Covered	2	8
27—Hard compact limestone	..	4
26—Covered	..	8
25—Coarse-grained crystalline argillaceous limestone	..	4
24—Covered	..	6
23—Limestone containing Gastropoda and *Rafinesquina*	..	6
22—Covered	5	..
21—Same as 18	..	3
20—Covered	1	..
19—Same as 18	..	4
18—Limestone coarsely crystalline, light colored	..	3
17—Sandstone	..	3
16—Same as 14	..	2
15—Same as 14	..	4
14—Drab crystalline limestone	..	3
13—Covered	..	6
12—Same as 10	..	5
11—Covered	6	..
10—Thin-bedded crystalline limestone	6	5
9—Covered	1	4
8—Coarse crystalline limestone	..	6
7—Covered	..	6

	Ft.	In.
6—Coarse crystalline limestone	..	10
5—Covered	10	8
4—Same as 2	..	3
3—Covered	..	2
2—Very hard compact limestone. *Rafinesquina*	..	9
1—Covered to level of road	150	..
Total section	255	..

In the bluff on the north side of Laughery Creek, a little over a mile west of Milton, the following section was measured: (§ 1.36 B)

	Ft.	In.
18—To top of hill. *Platystrophia*. *Hebertella*, etc., in loose pieces	38	6
17—Limestone with *Platystrophia laticosta*	..	3
16—Covered	19	..
15—Same as 11	..	8
14—Covered	9	6
13—Same as 11	..	3
12—Covered	5	6
11—Coarse crystalline limestone, gray mottled with yellow	..	3
10—Covered	2	
9—Thin-bedded limestone with *Rafinesquina*, crinoids, etc	1	2
8—Covered	4	2
7—Very coarse gray crystalline limestone. *Rafinesquina* (fragments) very abundant	.	4
6—Covered	43	..
5—Limestone with Bryozoa	..	6
4—Covered	48	..
3—Crystalline limestone with *Dalmanella*	..	6
2—Covered to road	43	4
1—Covered to creek level	20	..
Total section	237	..

In the north bluff of Laughrey Creek, one mile south of the mouth of Hayes branch, is the following section: (§ 1.36 C.)

	Ft.	In.
45—Covered to top of hill	40	..
44—Same as 43	10	..
43—Limestone with *Platystrophia* and *Hebertella*	1	..
42—Covered	5	6
41—Coarse crystalline limestone streaked with yellow. *Rafinesquina*	..	8
40—Partly covered. Limestone with *Rafinesquina*	12	6
39—Drab to bluish compact limestone, no fossils	..	8
38—Coarse gray crystalline limestone	1	4

	Ft.	In.
37—Covered	10	..
36—Coarse limestone streaked with yellow. Contains Bryozoa	1	6
35—Covered	4	..
34—Very hard compact limestone. Lower layer contains Brachiopoda and Bryozoa	..	3
33—Limestone containing large numbers of *Rafinesquina*	1	3
32—Covered	5	..
31—Coarse limestone. *Rafinesquina*	..	6
30—Covered	1	9
29—Limestone with layer of sandstone at the top	..	8
28—Covered	2	4
27—Limestone with Bryozoa and crinoids	..	7
26—Covered	1	4
25—Coarse blue limestone streaked with sandstone	1	..
24—Covered	1	8
23—Blue coarse-grained limestone with Brachiopoda and Bryozoa	..	4
22—Covered	..	6
21—Coarse-grained blue compact limestone	..	3
20—Covered	20	9
19—Coarse lumpy argillaceous limestone. Bryozoa	..	7
18—Covered	..	6
17—Very coarse, ferruginous, Bryozoal limestone	1	2
16—Covered	5	4
15—Yellow-mottled limestone. Bryozoa	..	5
14—Covered	5	..
13—Blue coarse limestone. Fragment of *Rafinesquina* very abundant.	..	5
12—Covered	1	2
11—Fine grained limestone. Bryozoa	..	6
10—Covered	3	4
9—Gray limestone with large white crystals of calcite. Many fragments of fossils	..	9
8—Covered	16	..
7—Coarse, crystalline, drab, unfossiliferous limestone	..	3
6—Covered	1	6
5—Thin limestones. Bryozoa very abundant	..	1
4—Coarse gray crystalline limestone. *Dalmanella* (aa)	..	5
3—Covered	22	..
2—Blue-mottled crystalline limestone	..	5
1—Covered	50	..
Total section	235	

Level of the creek.

Just south of the Weisburg station, in the bank of the creek to the west of the railroad, the upper layers of the Ordovician are exposed. From this exposure a large and very satisfactory collection of fossils was obtained. A section at this point is as follows (§ 1.34 A):

	Ft.	*In.*
15—A number of feet of barren limestones		
14—Blue compact fine-grained limestone. No fossils	1	..
13—Covered	5	..
12—Compact limestone. *Rhynchotrema capax*	..	6
11—Thin-bedded limestone	1	..
10—Very compact, fine-grained limestone	..	8
9—Calcareous shale with *Strophomena*	..	7
8—Limestone. Fragments of *Asaphus*	..	4
7—Shale	..	9
6—Limestone with *Hebertella*	..	3
5—Limestone same as 4	..	8
4—Blue limestone with *Rafinesquina* edgewise (aa)	..	3
3—*Rafinesquina* flatwise (a)	..	3
2—Shale	..	2
1—Coarse compact limestone, no fossils	..	10
Total section	12	

Level of creek below railroad culvert.

Continuing on down the creek from this point, the following layers are passed over (§ 1.34 B):

	Ft.	*In.*
4—Limestone	..	8
3—Irregular lumpy shale	2	6
2—Limestone and shale with *Rafinesquina* and *Hebertella*	1	4
1—Very coarse-grained limestone. *Rhynchotrema* (aa)	2	3

Down stream from this point no measurements were made, owing to the effect of rainy weather upon the barometer, but the characteristic fossils of the successive layers were noted. These are as follows from the last mentioned layer downward (§ 1.34 C):

16—*Plectambonites sericea* (aa).
15—*Strophomena rugosa* (aa).
14—Barren shale.
13—*Strophomena*.
12—*Streptelasma* (aa).
11—*Hebertella* (aa).
10—*Streptelasma*.
9—*Leptæna rhomboidalis* (aa).

8—*Dinorthis subquadrata* (a).
7—*Heberteila occidentalis* (a).
6—*Rafinesquina, Streptelasma, Platystrophia, Leptœna.*
5—*Rafinesquina, Monticulipora.*
4—*Dalmanella* (shaly limestone).
3—*Rafinesquina.*
2—*Asaphus, calymene. Rafinesquina.*
1—*Rafinesquina.*

Rafinesquina remains the dominant fossil for some distance farther down the creek, where its place is taken by the several varieties of *platystrophia biforata.*

No good sections of the Ordovician are to be found in the vicinity of Rising Sun. Numerous exposures of the various members may, however, be seen at a number of points. These exposures show that the lower members are, as in the other localities already studied, characterized by the great abundance of *Dalmanella* and *Plectambonites.* These fossils are succeeded in the beds next above by a number of species of *Trepostomata,* which in places completely fill the rocks.

Above the Bryozoa beds *Rafinesquina alternata* becomes abundant, though of course occurring in limited numbers at almost every level. Next follows the zone of *Platystrophia biforata* and its varieties. This is in turn succeeded in the tops of the hills by a zone in which a varietal form of *Rafinesquina alternata* is abundant, to the exclusion in places of almost every other fossil. The higher zones are not present in the vicinity of Rising Sun.

Vevay, in Switzerland county, is one of the best localities in the State for the collection of Ordovician fossils, and especially of the various forms of Platystrophia. Two detailed sections were measured at this place. These are designated A and B. Section A begins at the head of Main Cross street and extends up the little gully just east of the Orphan Asylum.

This section (A) is as follows (§ 1, 38 A.):

	Ft.	*In.*
87—Covered to the top of the hill	80	..
86—Limestone with *Platystrophia* and *Hebertella*	6	..
85—Yellowish argillaceous sandstone	..	4
84—Thin-bedded limestone containing *Platystrophia* and *Hebertella*	12	..
83—*Platystrophia biforata*	..	6
82—Yellow sandstone	..	4
81—Covered	3	3
80—Argillaceous arenaceous limestone	..	4
79—Some covered, mostly thin layers with *Rafinesquina*	14	..
78—Limestone with *Rafinesquina* and Bryozoa	..	5
77—Covered	3	8
76—Compact limestone with *Rafinesquina*	..	4

	Ft.	In.
75—Covered	..	6
74—Same as 72	3	8
73—Covered	1	3
72—Coarse-grained limestone *Zygospira Bryozoa*	..	4
71—Covered	3	..
70—Fine-grained limestone. *Zygospira*	..	3
69—Shale	..	6
68—Coarse limestone *Rafinesquina* (aa)	..	5
67—Covered	1	8
66—Thick, coarse, light gray limestone. Fragments of *Rafinesquina* (aa). *Zygospira* (c)	1	..
65—Thin-bedded light colored limestone. Bryozoa	8	..
64—Covered	6	..
63—Bryozoal limestone	..	6
62—Covered	..	8
61—Limestone. *Dalmanella* (aa)	1	2
60—Covered	8	8
59—Dark drab limestone. *Dalmanella*	..	4
58—Covered	2	..
57—Compact limestone with *Dalmanella* (aa)	..	7
56—Covered, probably limestone	25	..
55—Coarse limestone with large white crystals of calcite	..	6
54—Shale	..	6
53—Limestone, fragments of *Rafinesquina* (aa)	..	3
52—Shale	..	10
51—Limestone flecked with large flakes of calcite	..	3
50—Shale	2	8
49—Coarse grained limestone. *Dalmanella* (aa)	..	6
48—Shale	1	..
47—Limestone with *Dalmanella* and Bryozoa	..	3
46—Yellow weathering shale	2	..
45—Thin layers of limestone with *Dalmanella*	5	..
44—Shale	2	3
43—Layers of calcareous sandstone	..	6
42—Shale	3	..
41—Limestone	..	2
40—Shale	3	8
39—Crinoidal limestone	..	8
38—Shale	5	..
37—Bryozoal limestone in thin layers	2	6
36—Shale and thin limestone	2	6
35—Bryozoal limestone	5	..
34—Shale	2	..
33—Massive hard limestone. Fragments of *Dalmanella* and Bryozoa	..	10

	Ft.	In.
32—Thin limestone and shale. *Dalmanella*	2	4
31—Limestone. Very perfect specimens of *Dalmanella* (aa)	..	4
30—Shale	1	8
29—Limestone. *Rafinesquina* (aa)	..	7
28—Shale	..	8
27—Sandstone	..	4
26—Shale with thin layers of limestone	6	3
25—Dark crystalline limestone. Few fossils	..	4
24—Shale	5	4
23—Limestone. Crinoids. Bryozoa. Trilobites. *Dalmanella*	..	7
22—Shale	2	6
21—Limestone. Fragments of Trilobites and *Dalmanella*	..	3
20—Shale	..	7
19—Thin layers of limestone with intercalated shale	1	..
18—Shale	7	..
17—Limestone. Fragments of *Dalmanella*, *Rafinesquina* and Bryozoa	..	3
16—Shale	2	6
15—Same as 13	..	6
14—Shale	..	5
13—Compact Bryozoal limestone	..	3 to 5
12—Shale, with occasional layers of limestone containing stems of Bryozoa	6	4
11—Limestone spotted with argillaceous material and containing large Bryozoa	..	3
10—Shale with occasional thin lenticles of limestone	2	3
9—Thin layers of fine-grained compact limestone containing *Dalmanella* and Bryozoa	1	..
8—Shale	1	..
7—Limestone with argillaceous material in spots. Contains *Dalmanella*	..	5
6—Shale	4	..
5—Same as 3	..	10
4—Shale	4	6
3—Dark blue crytalline limestone. *Plectambonites* and *Dalmanella* (aa)	..	6
2—Blue clay shale	6	..
1—Covered to river level	101	..
Total section	389	..

Along the road (not the pike) running over the hill back of Vevay most of the rocks of section A are exposed together with *all* of the rocks represented by No. 87 (covered) of that section. The latter are very important, inasmuch as they include the greater part of the platystrophia beds, here ideally exposed for the collection of fossils. In fact several hundred specimens of this species were

obtained, most of them in an excellent state of preservation. An exact record was kept of the layer from which each specimen came, thereby rendering the material of the utmost value for the study of variation.

This section (B) is as follows (§1.38 B):

	Ft.	In.
60—Heavy compact limestone. Few fossils	27	..
59—Shaly limestone with *Platistrophia lynx*. *Hebertella*, *Monticulipora*, etc., *P. laticosta* toward the top	49	..
58—Shaly limestone. *Hebertella* (aa) some *Platystrophia* and *Rafinesquina*	10	8
57—Shaly limestone. *Rafinesquina* and *Hebertella*	2	..
56—Thin argillaceous limestone	16	..
55—Limestone. Base of *Platystrophia* zone	..	3
54—Limestone	..	3
53—Limestone. *Rafinesquina*	2	10
52—Limestone with *Zygospira*	..	5
51—Limestone with *Rafinesquina*	6	4
50—Very coarsely crystalline gray white-spotted limestone	..	6
49—Sandstone	..	1
48—Crinoidal limestone with fragments of *Raf.* (aa)	..	4
47—Covered	7	..
46—Mostly limestone with *Rafinesquina*	5	4
45—Fine grained limestone with *Rafinesquina*	..	2
44—Covered	2	4
43—Limestone with Bryozoa (aa)	..	3
42—Limestone with *Rafinesquina*	..	5
41—Covered	1	10
40—*Rafinesquina*. Bryozoa	..	8
39—Covered	17	..
38—Thin layer of light colored limestone with *Rafinesquina* (shells weathering red)	1	3
37—Covered	2	4
36—Same as 35	1	..
35—Limestone with *Dalmanella* (aa). Bryozoa (aa) *Rafinesquina* (fragments)	4	..
34—Limestone. Soft, gray. *Dalmanella* (aaa)	1	6
33—Covered: some exposed shale and limestone	12	..
32—Thin limestones	1	8
31—Coarsely crystalline light gray limestone containing *Dalmanella* and Bryozoa	..	8
30—Covered	5	6
29—Compact limestone. *Dalmanella* and Bryozoa	1	..
28—Shale	..	4
27—Limestone	..	4
26—Shale	7	..

	Ft.	In.
25—Limestone. *Dalmanella* (aa) Bryozoa. Fragments of *Rafinesquina*	1	3
24—Shale with thin layers of Bryozoal limestone	4	..
23—Bryozoal limestone with some shale	4	4
22—Shale	2	2
21—Limestone with Bryozoa and *Zygospira*	..	5
20—Shale	1	2
19—Bryozoal limestone	..	4
18—Shale	..	10
17—Thin layers of Bryozoal limestone	1	9
16—Shale	1	6
15—Two four-inch layers of Bryozoal limestone	..	8
14—Blue shale	5	4
13—Bryozoal limestone	..	6
12—Mostly compact Bryozoal limestone	5	..
11—Coarse crystalline Bryozoal limestone	..	10
10—Covered, probably shale	5	6
9—Limestone and shale. *Dalmanella*	2	6
8—Layers of limestone with *Dalmanella* Bryozoa, etc.	1	..
7—Covered, probably shale	2	2
6—Compact limestone with *Dalmanella*. Lower part consisting of sandstone	..	8
5—Covered	5	6
4—Limestone with *Rafinesquina* (aa)	..	6 to 8
3—Shale	5	6
2—*Dalmanella* layer	..	..
1—Covered to river level	140	..
Total section	385	..

The *Platystrophia* beds are to be seen about Mt. Sterling and in the banks of the east branch of Indian Creek. They reach the bed of the creek two miles northwest of the former place. In the bed of the creek just west of Mt. Sterling the zone of *Dalmanella* is exposed and extends up the creek for a mile and a half. Here it is succeeded by the *Rafinesquina* zone and then by the *Platystrophia* zone, as stated. One mile northwest of Bennington along the road the zone of *Rhynchotrema capax* is exposed, and between the latter place and the *Platystrophia* zone are abundant exposures of the upper zone of *Rafinesquina*. Large collections were obtained from all of these zones and await description in another paper.

The Ordovician and Silurian rocks of Madison, Jefferson County, Indiana, have for many years been the subject of more or less detailed study by geologists and paleontologists. The sections of the Madison hill in the railroad cut as given by Owen and Borden* are certainly far from being accurate. The writer

*Geol. surv. Ind., 1874, E. T. Cox; pp. 164-166.

obtained from Mr. W. B. Blake, engineer of the P., C., C. & St. L. Railway, accurrate data in regard to the per cent. of grade, length and depth of the cuts, and distance between same, for the steep Madison hill grade of the road above mentioned. The elevation of the terrace upon which Madison stands is approximately 60 ft. above river level, and the elevation of North Madison above Madison is 427 ft. The old reservoir at the south end of the big cut is given in Borden's report (loc. cit.) as 210½ ft. above low water of the Ohio River. The data given me by Mr. Blake are as follows: Grade, five and eighty-nine one-hundredths per cent. (5.89%); distance of south end of south cut from low water mark on north side of Ohio River, 2,700 ft.; distance through south cut, 800 ft.; distance from north end of south cut to south end of north cut, 1,100 ft.; distance through north cut, 1,100 ft.; besides this there are north of the north cut about 1,500 ft. of cut in places 40 ft. deep. The maximum depth of the south cut is 60 ft. and of the north cut 100 ft. The section which follows was measured independently of these figures and departed very little from them. One or two corrections have been made, however, in accordance with the above data. Section of the cut at Madison (§1.12 A.):

	Ft.	*In.*
71—Massive whitish limestone	10	.
70—One layer of bluish-white limestone	5	..
69—Thin-bedded limestone like No. 70	5	..
68—Blue shale	2	6
67—White arenaceous limestone	3	10
66—Shaly sandstone and shale	8	3
65—Massive white arenaceous limestone (Niagara)	2	6
64—From a few inches to nearly a foot of pinkish or yellowish to salmon colored crystalline limestone (Clinton?)	1	..
63—Massive white arenaceous limestone	4	2
62—Thick-bedded argillaceous arenaceous limestone	9	8
61—Same as 62, but banded on weathered surface with pink, gray, and buff	12	10
60—One massive conspicuous arenaceous layer	3	6
59—Thin-bedded, argillaceous, arenaceous, weathering brownish, with some calcareous layers containing Bryozoa	7	..
58—Nothing to four inches of coarse limestone with Ordovician fossils	..	4
57—Sandstone with lenticles of limestone containing Bryozoa	3	..
56—Argillaceous layer. *Faristella stellata*	2	..
55—Shale	6	..
54—*Faristella stellata*	1	2
53—Thin layers of limestone alternating with argillaceous and sandy layers. Bryozoa (aa). *Rafinesquina. Hebertella*	5	3
52—Massive soft sandstone	7	8

	Ft.	In.
51—Blue fossiliferous limestone shale and arenaceous layers.........	6	..
50—Fine shale with layers of limestone, *Rhynchotrema*, *Hebertella*, *Monticulipora*, *Calymene*, *Rafinesquina*	10	..
49—Same as 50. *Strophomena*, *Streptelasma*, *Plectambonites*, *Dalmanella*, *Platystrophia laticosta*, *Ambonychia*	8	..
48—Probably shale and thin layers of limestone; covered by talus ...	22	..
47—Heavy layers of limestone seen in the *west* side of the south cut, at the top.		
46—Heavy layers of limestone seen in the *east* side of the south cut, at the top.		
The lowest layers in the big cut (north cut) are 24 feet above the top of No. 45 if the foot of the big cut be taken as 210 feet above the river. Part of the layers of No. 46 would therefore be repeated in 45. Allowance is made for this fact. Nos. 46 and 47 together	24	..
45—Shale. The top of No. 45 is at the culvert just north of the south cut..	10	..
44—Several layers of limestone with *Cyclomena*, *Rafinesquina*, *Calymene*, etc	1	2
43—Shaly limestone. *Cyclonema*	2	8
42—Limestone. *Ambonychia*, *Cyclonema*, *Rafinesquina*, *Monticulipora*, Crinoids	2	..
41—Limestone and shale. *Ambonychia*............................	5	..
40—Compact close-grained limestone. *Rafinesquina*................	..	3
39—Limestone and shale. *Zygospira*, *Ambonychia*..................	2	4
38—Limestone. *Rafinesquina* edgewise (aaa)	..	4
37—Argillaceous compact limestone. *Rafinesquina*..................	6	9
36—Limestone. Bryozoa	..	6
35—Shaly limestone..	5	8
34—Limestone	..	8
33—Shaly limestone..	2	8
32—Limestone. *Rafinesquina*, *Calymene*, *Hebertella* (?), Gastropoda, Bryozoa	..	8
31—Shale, with occasional 2-inch to 3-inch layers of limestone.......	10	8
30—Limestone. *Rafinesquina* edgewise (aaa)........................	..	3
29—Shaly limestone. *Rafinesquina* (aa), *Modiolopsis* (aa), *Zygospira* (aa)...	6	9
28—Similar to 26..	..	4
27—Shaly limestone..	1	4
26—Blue fine-grained limestone. *Zygospira* (aaa)..................	..	3
25—Shaly limestone. *Rafinesquina*, etc	13	..
24—Very compact fine-grained limestone; no fossils.................	..	6
23—Shale and limestone, with excellently preserved specimens of *Rafinesquina* (aa)..	4	2

	Ft.	In.
22—Limestone, with top of layer composed of immense numbers of *Zygospira modesta*	..	3
21—Rather coarse shale	2	..
20—Lumpy, shaly limestone. *Asaphus*, *Rafinesquina*	3	..
19—Coarse to fine-grained barren limestone	..	8
18—Lumpy, shaly limestone. *Rafinesquina* (aa), Trilobites (a), *Zygospira*, Streptelasma, Bryozoa	12	..
17—Limestone, with *Rafinesquina*, *Zygospira* (aa), Bryozoa, *Orthoceras*.	5	10
16—Shale, with thin layers of limestone	1	..
15—Very compact, fine-grained blue barren limestone	..	6
14—Shale	..	8
13—Compact limestone. *Calymene*, *Zygoapira*, etc	..	5
12—Limestone. *Calymene* (aa), Bryozoa, *Rafinesquina*, *Orthoceras*	1	3
11—Shale, with thin layers of limestone	3	8
10—Thin argillaceous limestone with *Calymene* and Bryozoa (a)	1	..
9—Massive blue limestone. *Rafinesquina*, Trilobites, Bryozoa	..	7
8—Limestone. *Rafinesquina*, *Zygospira*, Bryozoa	2	9
7—Thin argillaceous yellow-spotted limestone. *Platystrophia*, *Hebertella*. *Rafinesquina*, Bryozoa	1	..
6—Limestone. *Hebertella* (aa), *Rafinesquina nasuta*, *Platysstrophia lynx*.	1	2
5—Bryozoal limestone	..	4
4—Covered, probably shale	1	..
3—Limestone with Trilobites, *Zygospira*, etc	..	2
2—Coarse crystalline limestone. *Hebertella*	..	6
1—Covered to river level	62	..
Total section	357	

Number 7 of this section represents the top of the Platystrophia zone. At Vevay the top of the same zone is 358 feet above river level, and at Lawrenceburg about 390 feet. The Madison section affords an excellent opportunity to study the upper Rafinesquina zone. It is in the upper zone that this fossil is so constantly associated with *Zygospira modesta* and a number of species of Lamellibranchs. In the lower zone it has no such constant associates.

Section along Clifty creek (§ 1.12 B):

	Ft.	In.
22—Limestone. *Rafinesquina*, Lamellibranchiata, Gastropoda, Crinoids	..	6
21—Limestone and coarse lumpy shale	7	4
20—Shale and limestone. Top, a heavy layer of limestone with conspicuous wave-like markings	21	4
19—Partly covered, but represented by heavy layers of limestone in the bank above 18	11	..
18—Limestone and shale	14	4
17—Limestone. *Rafinesquina* (aaa), *Hebertella*	5	..

	Ft.	In.
16—Shale, shaly limestone, some thick layers of limestone. *Rafinesquina*, Bryozoa, Trilobites, *Zygospira* (aaa) in some layers......	40	..
15—Heavy layer of limestone..	..	6
14—Shale and shaly limestone. Trilobites (a)......................	9	6
13—Limestone. *Rafinesquina*, *Asaphus*, *Calymene*, *Platystrophia*........	8	6
12—Mostly shale	4	10
11—Argillaceous compact layer. Trilobites, Gastropods.............	..	6
10—Shaly limestone..	2	9
9—Limestone and shale. *Platystrophia*. *Hebertella*.................	3	..
8—Limestone. *P. lynx* and *laticosta*. *Hebertella*....................	3	6
7—Covered	10	..
6—Limestone, more shaly than 5. *Hebertella* (form with dorsal fold), *P. lynx* and *laticosta*..	3	..
5—Same as 4 but *P. laticosta* more abundant	3	10
4—Thin shaly limestone. *Hebertella*	1	2
3—Thin shaly limestone. *Hebertella*, *P. laticosta*, *Monticulipora* (aa).	1	..
2—Thin shaly limestone. *P. lynx* (aa), *laticosta* (a), *Hebertella occidentalis* (c) Trilobites, *Monticulipora*	1	..
1—Covered to river level...	45	..
Total section.......	198	

This section shows some 30 feet more of the Platystrophia beds than the Madison section; otherwise it is the same in the main as the basal part of that section.

P. lynx is here abundant in the lower layers and *laticosta* in the upper layers.

From the detailed sections now described of the Ordovician rocks of Indiana it will at once be seen that there are certain well-defined faunal zones which may be traced without fail over the whole area. It has long been known that the zone characterized by the presence in abundance of *Platystrophia*, forms a well-marked and persistent stratum; but apparently the other zones, if recognized at all, have been minimized in importance. Any one of them is however as persistent and as easily traced as the Platystrophia zone.

These zones are in ascending order as follows (the thickness is given in parentheses):

1—Dalmanella multisecta (200–240 feet).
2—Rafinesquina alternata 50–70 feet).
3—Platystrophia (60–80 feet).
4—Rafinesquina alternata var. fracta (100 feet ±).
5—Dalmanella Meeki (20 feet ±).
6—Streptelasma.
7—Strophomena (10 feet ±).
8—Rhynchotrema capax (10 feet ±).

Some Developmental Stages of Orthothetes Minutus N. Sp.

By Edgar R. Cumings.

The specimens discussed in this paper are from the abandoned quarry known as the Cleveland Stone Company's quarry, located one mile north of Harrodsburg, Monroe County, Indiana. This quarry is in the so-called Bedford limestone, and the specimens come from the top of the quarry—and also from near the summit of the formation. They are, so far as I can ascertain without having seen the original specimens of Hall,* specifically the same as Spergen hill forms referred by the latter gentleman to the Orthis (Terebratulites) umbraculum of Schlotheim.†

Description of the shell:

Shell semiovate to subquadrate in old individuals; hinge line usually less than the greatest width of the shell, especially in young individuals; cardinal extremities forming an obtuse, or sometimes a right angle with the lateral margins. Surface finely plicated; plications increasing toward the margin by interstitial addition. Crests of the plications crenulated by equally spaced fine concentric lines.

Ventral valve concave with a pronounced tendency to irregular growth about the beak. In mature individuals the beak becomes strongly retrorse and is greatly elevated, equaling in height one-half the length of the shell. Area well defined, flat, showing in well preserved specimens a low ridge on each side of the prominent deltidium and parallel with its margins. The younger specimens seem to show a perforation at the apex of the deltidium.

Dorsal valve regularly convex, greatest elevation about one-third of the way from the beak to the front margin, though there is considerable variation in this respect in shells of different age. Usually some flattening at the cardinal extremities. Area very narrow or usually scarcely at all conspicuous.

Interior of the ventral valve showing rather prominent teeth, which diverge widely. Cardinal process in the dorsal valve elevated, projecting

*Acting under the impression that some of the original specimens of Hall were in the Albany Museum, the writer sent a number of specimens of the form under consideration to Dr. John M. Clarke to compare with Hall's specimens. While owing to the fact that Hall's specimens are not at Albany, Dr. Clarke could not make the comparison, nevertheless he gives it as his opinion that the two are *probably* identical.

†Petrefk. I, 256; Schnurr, Brachiop. der *Eifel* 216; Bronn Lethæa Geog. I, 361. See Hall, Trans. Alb. Inst. 4, p. 12.

somewhat beyond the hinge line; notch shallow, the grooves on the posterior faces of the apopnyses very faint.

Ratio of breadth to length in an average adult specimen about as 11 to 8.

This species can not be referred to the *O. (Terebratulites) umbraculum* of Schlotheim, from which it differs in the less length of the hinge line, fewer number of plications, greater proportionate height of the area, which in the present species tends to become strongly retrorse in mature individuals, and the subquadrate rather than semicircular outline of the shells. The figures of Schlotheim's species also show it to possess a strongly quadrilobate cardinal process, while in the present form the notch in the process is very shallow and the grooves very faint.

The species to some extent resembles *O. lens*, from which it differs in the form of the cardinal process and in the greater proportionate length of the latter.

Development.—In the search for specimens of this rather rare species (about 50 specimens were found among several thousand of the common Spergen hill forms) a number of very young stages was obtained. While even the adult individuals share in the general stunting so characteristic of the entire Spergen hill fauna, no complete specimen in the writer's collection having a length of more than 5mm,* nevertheless these larger individuals present the usual features of maturity.

The smallest individual observed has a breadth of .9mm and a length of .6mm. In this specimen the ventral valve is roughly conical, though slightly more convex toward the beak, which projects over the hinge line and is very prominent. The surface shows 18 plications as against 40 in the largest individual observed, while the posterior third of the shell is without surface ornamentation except a few obscure concentric markings. The area is high and the deltidium less sharply marked off from it than in the older specimens. The dorsal valve has its greatest convexity at the center and is also smooth for a considerable distance from the beak. It shows no sign of an area.

Individuals of the length of 2mm have the area perpendicular to the plane of separation of the valves, and the ventral valve showing a slight concavity toward the front. The number of plications also has increased

*Since the above was written, the author has found at Stinesville, Monroe County, Indiana, specimens of this species over one inch in breadth, but agreeing in all essential features with the adult specimens described here.

to 22 or 23, and the region of greatest convexity in the dorsal valve has approached, somewhat, the beak. The youngest individual is conspicuously shorter on the hinge line than farther forward. In fact it in every respect approaches the generalized type of Brachiopod shell, as Beecher & Clarke have shown to be the case in the species of the Waldron fauna.*

The Cold-Blooded Vertebrates of Winona Lake and Vicinity.†

By Earl E. Ramsey.

Winona Lake is located in sections 15, 16, 17, 21 and 22 of Township 32 north, Range 6 east, in Kosciusko County, Indiana. The main body of the lake is about one mile southeast of Warsaw. It is one of the series of lakes belonging to the Mississippi drainage system and is drained into the Tippecanoe River. It lies about six miles south of the watershed between the St. Lawrence and the Mississippi basins.

The lake is irregular in outline and has an area of 0.98 square miles. The greatest length is from north to south and is somewhat more than one mile. The average width is about five-eighths of a mile. The greatest depth is 81 feet.

The lake, like all the small lakes of northern Indiana, is of glacial origin. The catchment basin is large as compared with the size of the lake itself. Unusually heavy rains change the lake level as much as two to two and one-half feet. The tributary streams are three in number. The largest is Cherry Creek, which flows into the lake on the southeast. For the most part it flows through woodland. Two other streams, the larger of which is Clear Creek, enter the lake at its extreme southern part. The output of Clear Creek is nearly as much as that of Cherry Creek. Numerous springs on the Winona Assembly grounds drain into the lake. Lands lying to the north are drained into Pike Lake and Center Lake, both of which lie about one mile northwest of Winona Lake.

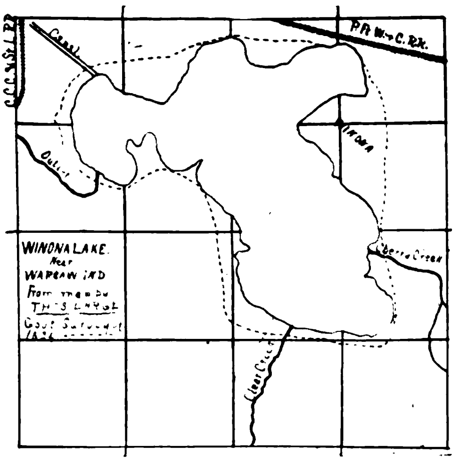
The outlet is situated at the southern part of a small bay connecting with the main lake on the northwest. It empties into Tippecanoe River at a point about one mile northwest of Warsaw.

The shore line, for the most part, is low. On the north, a small stretch of cultivated land rises rapidly to a ten-foot elevation line. The Winona Assembly grounds on the east have the greatest elevation. This

*Memoirs of the N. Y. State Museum, Vol. I, No. 1.

†Contributions from the Zoölogical Laboratory of the Indiana University, C. H. Eigenmann, Director, No. 39.

elevation is from ten to fifty rods back from the lake. The other parts of the ground lie below a ten-foot line. The south shore is uniformly low and swampy. On the west, an abrupt raise is found at Yarnelle's Landing. To the north of the landing, the shore is low, and the elevation gradual. Natural woodland is found at Yarnelle's, at the outlets of both Clear Creek and Cherry Creek and on the Assembly grounds.



The shores are about equally divided between sand and turf formation. A peninsula extending into the lake from the Winona grounds is of turf. On the south a great part of the shore, as well as the shore of the bay on the west of the main lake, is of such a formation. Other parts are sandy. In a general way, that part of the land which has lately been reclaimed from the lake has a coast line formed of decayed plant life—turf.

By reference to the map of Eagle Lake (now Winona Lake) prepared by the U. S. Survey in 1834, it will be seen that the lake was considerably larger at that time than now. The difference in the lake has been brought about, first by dredging the outlet channel and lowering the level of the lake; second, by the encroachment of plant life upon the lake proper, and the luxuriant plant life on the land partially dried by lowering the lake level. As noted farther on, the plant life of the lake is abundant. The dense banks of Scirpus, Nuphar, etc., tend to collect material that may float into them, and they also contribute their own growth to the formation of new lake bottom. A third agency which has acted in some parts of the lake—notably the southern part—is that of the ice. With the lowerin of the lake level, stretches of lake bottom were left barely covered by

water and were in most cases separated from the land by deeper water. As the ice formed, it pushed the ground higher on these shallow places. The ice cracks in excessively cold weather, the cracks fill with water and freeze again. This crowds the ice and the substratum of earth still farther shoreward. Very much of the south shore of the lake shows such a formation. The ice-beach near the outlet of Clear Creek is at least thirty inches above lake level and separates a dense swamp from the lake. In this swamp thus isolated from the main lake, the semi-aquatic plants readily establish themselves and thus finally reclaim the swamp land.

The plant life in the lake is abundant. A bank of Scirpus practically encircles the lake. Nuphar, Nymphaea, Typha, Potamogeton, Ceratophyllum and Chara are also abundant. The outlet is now entirely "overgrown" by Nuphar, Nymphaea, Typha and Scirpus arranged in water zones.

The average temperature of the water from July 6 to August 23, 1899, at a depth of two feet, was 80°; the air temperature for the same time was 81.5°. The deep water of the lake marked 41° and was, of course, subject to no diurnal changes, nor even to any considerable seasonal variation. The prevailing winds during the summer months are west to southwest.

THE FISHES.

The number of species of fishes thus far secured is forty-one. Considering the great variety of physical conditions, the number of species is small. But the number of individuals in each species is much more disappointing. The scarcity of the larger food fishes is due to the great amount of fishing in the lake. But the scarcity of the smaller fishes, the Cyprinidae, many species of the Darters, Labidesthes, etc., is not accounted for in this way.

To show the relative numbers of a very common form which serves as food for the larger species, I may take the Labidesthes sicculus. As many as a gallon of this form may be secured in either Turkey Lake or Tippecanoe Lake at a single haul of the seine. Not more than three or four dozen were secured in Winona Lake during the entire summer. This fact in itself will partially account for the scarcity of the larger food fishes. The same relative proportions are true of many other forms. The following list gives the species and locality from which they were secured. The column marked (N)* gives some notion of the relative abundance

* In some cases the number of specimens collected is marked; (+) indicates that the species is abundant; (·), not so abundant; (—), but few.

ance. Thirteen families are represented and thirty-three genera. The +'s in the other columns indicate the localities in which the various species are found.

SPECIES.	Cherry Creek.	Clear Creek.	Lake.	Outlet.	Tippecanoe R.	N.
Lampetra wilderi, Gage				+		1
Lepisosteus osseus (L)			+			1
Lepisosteus platostomus, Rafinesque			+			×
Amia calva, L			+			—
Ameiurus nebulosus (Le Sueur)			+			×
Ameiurus melas (Rafinesque)				+		2
Schilbeodes gyrinus (Mitchill)				+		3
Carpiodes (Sp——)*			+	+		2
Catostomus nigricans, Le Sueur	+	+	+	+		×
Catostomus commersoni (Lacépède)		+				—
Erimyzon sucetta oblongus (Mitchill)				+		×
Minytrema melanops (Rafinesque)		+				1
Campostoma anomalum (Rafinesque)	+	+				+
Pimephales notatus (Rafinesque)	+		+			+
Notropis whipplei (Girard)	+		+	+		+
Notropis cornutus (Mitchill)	+			+		×
Hybopsis kentuckiensis (Rafinesque)	+	+				—
Semotilus atromaculatus (Mitchill)	+	+		+		+
Abramis crysoleucus (Mitchill)			+			×
Umbra limi (Kirtland)	+					5
Lucius vermiculatus (Le Sueur)	+		+	+		×
Fundulus notatus (Rafinesque)			+			+
Fundulus dispar (Agassiz)				+		—
Labidesthes sicculus (Cope)	+		+	+		—
Pomoxis sparoides (Lacépède)			+			1
Ambloplites rupestris (Rafinesque)	+			+	+	+
Chænobryttus gulosus (Cuv. and Val.)	+		+	+		×
Lepomis pallidus (Mitchill)	+		+	+	+	+
Lepomis megalotis (Rafinesque)				+	+	×
Eupomotis gibbosus (Linnaeus)	+		+	+		×
Micropterus dolomieu Lacépède					+	5
Micropterus salmoides (Lacépède)			+	+	+	+
Percina caprodes (Rafinesque)	+		+		+	×
Hadropterus aspro (Cope and Jordan)	+		+		+	3
Boleosoma nigrum (Rafinesque)	+	+	+	+	+	+
Diplesion blennioides Rafinesque					+	2
Etheostoma iowæ, Jordan and Meek	+			+		—
Etheostoma coeruleum, Storer	+	+	+	+	+	+
Microperca punctulata, Putnam				+		—
Perca flavescens (Mitchill)	+		+	+		×
Cottus ictalops (Rafinesque)	+	+		+		+

*Two large specimens taken by fishermen were seen. The species was probably C. Velifer (Rafinesque), but no positive identification further than genus could be made.

BATRACHIANS.

This group is represented by but few species.

1. Necturus maculosus (Rafinesque). Three or four specimens were found by workmen who were deepening the channel of Cherry Creek.

2. Bufo lentiginosus americanus (Le Conte).

3. Acris gryllus gryllus (Le Conte).

4. Acris gryllus crepitans (Baird).

5. Hyla versicolor (Le Conte). But two specimens of this interesting little animal were taken.

6. Rana pipiens Kalm. This is the most abundant of the frogs.

7. Rana clamitans Latreille. The individuals of this species are nearly as numerous as those of R. pipiens.

8. Rana catesbeana Shaw. But one or two specimens found.

SNAKES.

Eight species of snakes have been found:

1. Storeria dekayi (Holbrook), is rare.

2. Clonophis kirtlandi (Kennicott). Only two or three specimens were taken.

3. Two varieties of the garter snake, Thamnophis sirtalis parietalis (Say), and Thamnophis sirtalis sirtalis L., were taken. This snake is the most abundant of the forms found in this locality. On July 19, a female bearing thirty-one well developed embryos was killed. On August 5, one kept in a pen gave birth to young. The number of young could not be ascertained.

4. Regina leberis (L.). The leather snake is abundant. It is third in this locality in point of number. On August 12, 1899, a gravid female was found having ten well developed embryos. Its haunts are along creeks.

5. Natrix sipedon (L.). This species is plentiful. On July 23, 1900, a female containing twenty-six embryos was killed. The water snake is a swamp-loving form, and is of a sullen and vicious disposition.

6. The blue racer, Bascanion constrictor (L) is the largest snake in this locality, and is comparatively abundant. When captured and put in a pen, it soon tames and seems to take delight in being handled. Its movements and shape are peculiarly graceful. Its food consists of frogs, garter snakes, etc. A specimen forty-two inches long swallowed a garter snake twenty-eight inches long. I have known it to lay its eggs about the middle of June, and have found the young hatching about the middle of September. Its egg-laying habit is worthy of note. One specimen selected the soft ground between two rows of potatoes and pushed her way under the ground. As she crawled along in this underground passage, the eggs, twenty-two in number, were laid in the channel which her body had made. Another laid her eggs in the hollow root of a half decayed stump. The eggs are white in color, and about one inch in length, and have a uniform diameter of one-half inch. The soft shell is so tough that it will sustain a weight of more than one hundred pounds without breaking. The young, when first hatched, are seven or eight inches in length. The first action when the little head is thrust through the shell is to stick out its tongue. The blue racer frequents the woods or high grass and weeds.

7. Lampropeltis doliatus triangulus (Boie) is found rarely.

8. Sistrurus catenatus (Rafinesque) is second in point of numbers. The garter snake is more plentiful than the prairie-rattler. During the summer of 1899 eleven specimens were caught, and nine were taken during the following summer. They are usually found in low land and run but little during the day unless disturbed. Nothing was learned concerning their food, since they persistently refused to eat when kept in confinement. A female kept in a pen gave birth to seven young on August 13. Several of the little ones were kept in a glass aquarium for a time. On August 17 they drank drops of water from a pipette and ate a few small bits of fresh meat. Three days later they began their first moult. They were about eight and one-half inches long at birth. A case was reported to me in which thirteen young were born. The adults are inoffensive and move slowly. They are easily captured by means of a noose slipped over their heads or by an insect net.

TURTLES.

The land and water forms together number eight species. Of these the soft-shelled turtle, the speckled tortoise, Blanding's tortoise and the box tortoise are rare. Even the commoner species are not very abundant. No more than two dozen eggs were found. They were of the Aromochelys odoratus (Latreille), and were laid in heaps of debris which had been washed up along the shore. The species are as follows:

1. Aspidonectes spinifer (Le Sueur).
2. Chelydra serpentina (L.).
3. Aromochelys odoratus (Latreille).
4. Graptemys geographicus (Le Sueur).
5. Chrysemys marginata (Agassiz).
6. Clemmys guttatus (Schneider).
7. Emydoidea blandingi (Holbrook).
8. Terrapene carolina (L.).

I desire to acknowledge the helpful suggestions of Dr. C. H. Eigenmann in the preparation of this brief report. Dr. S. E. Meek has also kindly aided me in preparing a partial catalogue of the fishes, and has mapped out the general plan of the paper.

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INDEX OF PROCEEDINGS 1891-1900

(INCLUSIVE)

[*] First published annual report of Proceedings.